"वसुधैव कुटुम्बकम्"

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Ministry of Education and Social Welfare
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March 26th - 31st 1972

VOLUME III–PART I

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Sanskrit and Science and Technology

Edited by
Prof. V. RAGHAVAN
Chairman, Academic Sub-Committee

Ministry of Education and Social Welfare
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PREFACE

The First World Sanskrit Conference was held under the authority and auspices of the Government of India from 26th to 31st March, 1972 in the Vigyan Bhavan, New Delhi. I had the honour, as Chairman of the Academic Sub-Committee, of organising the academic work of the Conference. In view of the special character and purpose of the Conference, the wide perspective and the particular focus aimed at, the subjects were framed in four Sections and contributions invited from scholars and participants from all over India and the world. Schedules of subjects were drawn for the four main Sections and invitations issued to chosen scholars who had made significant contributions in those subjects. Because of the enthusiasm that the Conference evoked in the country, it became necessary to accept papers from numerous scholars who sent their voluntary contributions and add a fifth Section of miscellaneous papers on diverse topics of research and also a Session devoted solely to Pandits and their Sanskrit papers.

The Sections and the subjects dealt with at the Conference were :

I. Contribution of Different Areas and Countries to Sanskrit. Development of Sanskrit Studies in different Areas and Countries.

II. Sanskrit and Other Languages and Literatures of India and the World and their Thought and Culture.

The Heritage of Different Branches of Sanskrit Literature and their National and International Significance.

III. Sanskrit and Archaeology, Arts and Education —Sanskrit and Science and Technology—Sanskrit and World Languages, Literatures, Thought and Culture—Sanskrit and Man, Universalism and Peace—Sanskrit and Western Literature and Criticism-Sanskrit in the Modern World.

IV. Papers on diverse topics of Sanskrit Language, Literature, Thought and Culture.

V. Pandita Parishad

Books of Summaries of the papers of the Sections were prepared in advance and placed in the hands of the participants. It was one of the largest of scholarly Conferences and about 600 papers were presented.

The arrangements for the printing of the Proceedings and the Papers of the Conference could be made only in 1973. Owing to the paucity of Presses which could handle Sanskrit and Indological research material, diacritical marks, Devanagari matter etc. and to the difficult labour situation in the Presses, the printing could not be speeded up. Printing was arranged concurrently in two different places, Madras and Delhi, and in three different Presses.

So far Volumes I and II, each in two parts, have been published. Vol. III, part I is now being published. It includes papers on Sanskrit and Archaeology, Arts and Education, Sanskrit and Science and Technology.

As in the case of the previous volumes Dr. S. S. Janaki assisted me in seeing the Volume through the press. I must thank also the authorities of the Ministry of Education and Officers in the Rashtriya Sanskrit Samsthan.

Thanks are due to the Madras Law Journal Press, who printed also a Volume of the Summaries of papers of this Conference, for their co-operation in the printing of this Volume. Especially in the papers on Scientific subjects the press had to specially draw a good number of diagrams and mathematical symbols.

V. RAGHAVAN,
(*Chairman, Academic Sub-Committee*)

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VEDIC TEXTS ON THE MANUFACTURE OF POTTERY

PROF. DR. WILHELM RAU,
University of Marburg, Federal Republic of Germany

In order to demonstrate the importance of Vedic Sanskrit texts for Indian archaeology, I propose to discuss here the making and the shape of two earthern vessels employed in Vedic ritual, namely the *ukhā* and the *mahāvīra*[1]. The former was used as a portable container of a sacrificial fire (*ukhya agni*), while the latter served as a boiling pot for milk in the *pravargya* ceremony. It would, no doubt, be much more interesting, if our literary sources furnished us with information on pottery used in everyday life, but there is, fortunately, a definite likelihood that the earthenware used on the sacrificial ground was not entirely different from the pottery employed for ordinary domestic purposes, in earlier times. Allowance must, I presume, only be made for the probability that in the ritual sphere primitive technical methods and obsolete shapes of vessels may have survived longer than in the secular sphere of life.

My sources are the four Saṃhitās of the Black Yajurveda, *i.e.* the *Maitrāyaṇī* the *Kaṭha*, the *Kapiṣṭhala-Kaṭha*, and the *Taittirīyasaṃhitā*, a fragment of a *Kāṭhakabrāhmaṇa*, the *Taittirīya-Āraṇyaka* and the *Śatapathabrāhmaṇa*[2]. I deliberately confine myself to the oldest literary strata, hoping in this way to get as close as possible to the Vedic period proper. The Śrautasūtras contain, it must be admitted, a certain amount of additional information[5], but I am convinced that they belong to historical rather than to pre-historic times and may reflect innovations in comparison with the older texts.

---

[1] Some efforts in a similar direction have occasionally been made, *e.g.*, in a few contributions to the book *Potteries in Ancient India*, edited by B.P. Sinha, Patna 1969, but the matter could, and should, be treated much more thoroughly.

[2] KaB [= *Kāṭhakabrāhmaṇa*]. Die Tubinger Kaṭha-Handschriften und ihre Beziehung zum Tâittirîya-âraṇyaka. Von L. von Schroeder. Herausgegeben mit einem Nachtrag von G. Buhler. Wien 1898. = Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien. Philosophisch-historische Classe. Band 137, IV.

KpS *Kapiṣṭhala-Kaṭha-Saṃhitā.* Ed. Raghu Vira, Delhi, 1968.
KS *Kāṭhakam.* Ed. Leopold von Schroeder. 3 vols. and index by W. Simon. Leipzig, 1900, 1909, 1901, 1912.
MS *Maitrāyaṇī Saṃhitā.* Ed. Leopold von Schroeder. 4 vols. Leipzig, 1881, 1883, 1885, 1885, 1886.
ŚB *Śatapatha-Brāhmaṇa.* Ed. Albrecht Weber. Berlin/London 1855.
TA *Taittirīya-āraṇyaka.* Ed. Ve. Śā. Rā. Rā. Bābāśāstrī Phaḍake. 2 vols. Poona, 1926.
TS *Taittirīya-Saṃhitā.* Ed. Anantaśāstrī Dhupakara. Pāraḍī 1957.

Figures in square [ ] brackets indicate pages and lines of the editions used.

[3] For the *ukhā* see : ĀpastambaŚ. 16, 4, 1 - 6, 1 ; BaudhāyanaŚ. S. 10, 1-8; MānavaŚ. S. 6, 1, 2, 1-2, 22 : VārāhaŚ. S. 2, 11, 33-48; VaikhānasaŚ. S. 18, 1-2 ; SatyāṣāḍhaŚ. S. 11, 1, 42-66 ; KātyāyanaŚ. S. 16, 3, 16 -4, 23 ; - for the *mahāvīrā* : ĀpastambaŚ. S. 15, 2, 1 - 4-10; BaudhāyanaŚ. S. 9-1-4 ; BhāradvājaŚ. S. 11, 2, 1 - 4-11 : MānavaŚ. S. 4, 2, 1, 14 - 29 ; VaikhānasaŚ. S. 13, 2 - 6; SatyāṣāḍhaŚ. S. 24, 1, 8-22 ; KātyāyanaŚ. S. 25, 15, 1-26.

Let me then familiarise you first with the gist of the relevant chapters of our sources, and in the second part of my paper, offer you some conclusions which, in my opinion, may be drawn from the facts ascertained in the first. Pre-historians specializing in ancient technology will perhaps be able to point out more.

UKHĀ

ŚB. 6. 4. 4. 18—6. 5. 4. 16 :

A suitable amount of clay (*mṛd*) is brought to an enclosed shed (*pariśrita*) on sacrificial ground and deposited on a moistened gravel (*sikatā*), covered mound (*uddhata*). Next, water wherein the red gum of Butea frondosa Koen (*parṇakaṣāya*) had been boiled, is poured over the clay and five materials are added : (1) foam (*phena*,—of what?), (2) goat's hair (*ajalomá*), ground powder (*piṣṭá*) of (3) lime pebbles (*śárkarā*), (4) stone (*áśman*) and (5) an unidentified metallic compound (*ayorasá*; according to J. Eggeling on ŚB. 6. 5. 1. 6 'iron rust'). This mixture is carefully kneaded, among others with the following mantras (*Vājasaneyi Saṃhitā* 11, 55-57) :

sáṁsṛṣṭāṁ vásubhī rudrair dhīraiḥ karmaṇyāṃ mṛdam |
hástābhyāṃ mṛdvīṃ kṛtvā sinīvālī kṛṇotu tām ||

The clay suitable for the work that has been mixed by the Vasus [and] by the skilful Rudras,—may Sinīvālī fashion it, after she has made it soft with her hands !

sinīvālī sukapardā sukurīrā svaupaśā |
sā tubhyam adite mahy okhāṃ dadhātu hástayoḥ ||

Sinīvālī of fair hair-tufts, of fair head-dress, of fair locks, may she, O great Aditi, pass thee the *ukhā* into thy hands !

ukhāṃ kṛṇotu śáktyā bāhubhyām áditir dhiyā |
mātā putráṁ yáthopásthe sāgniṃ bibhartu gárbha ā ||

May Aditi fashion the *ukhā* with ability, with her arms, with skill ! May she [scil. the *ukhā*] bear Agni in her womb like a mother, her son in her lap !

I have quoted these mantras fully, because they show that in early times the mixing of the clay and, as will be seen later, the firing of the pot was done by men, whereas the kneading was accomplished by one female and the fashioning by two of them together. In the ritual of the *Satapatha brāhmaṇa* it is the *yájamāna* who performs all this work, unaided.

The *ukhā* is hand-made by the strip — or slap work-method, not wheel-thrown, in such a way that, firstly, the flat base (*nidhi*) measuring one span (*prādeśá*) in diameter is spread out. Next, its edge (*tīra*) is turned up all-around, and then, successively, three rolls or strips of clay (*uddhi*) are ranged one upon another and pressed into union by daubing (*sáṃ-lip*) and continued moistening (*saṃ-ślakṣṇaya-*) the inside as well as the outside of the vessel. The total height should amount to a span (*prādeśá*), while the diameter could be either one or five spans, i.e. the length of an arrow (*iṣu*). On the upper, that is on the third roll (*uddhi*), probably on the joint between the second and the third roll, a horizontal belt (*rāsnā*) is pasted, and to further strengthen the lower sides of the vessel, four vertical bands (*ūrdhvā*) applied, reaching from the base up to the horizontal belt just mentioned. At their ends they run into nipples (*stana*). The ŚB insists that they should be four in number, neither less (i.e. two) nor more (i.e. six or eight) as older ritual authorities permitted. Last of all, the mouth (*bila*) is fashioned. Upon completion, the *yájamāna* sets the *ukhā* down with the *mantra* (VS 11, 58) :

> *kṛtvāya sa mahīm ukhāṃ mṛnmáyīṃ yonim agnáye* |
> [*etāṃ*] *putrébhyaḥ prāyacchad aditiḥ śrapáyān iti* ||

Having fashioned the great *ukhā*, the earthen womb for Agni, Aditi gave it to her sons [with the intention] : 'Let them bake it' !

Before firing, however, the raw vessel is fumigated (*dhūpaya-*), i.e. dried 'leather hard', with seven balls of smouldering horse-dung.

For the baking, a square (*cátuḥsrakti*) pit (*kūpa*) is dug in the ground. Its bottom is covered with fuel (*pácana*). Several Śrautasūtras prescribe that here, as also for the baking of the *mahāvīrá*, such materials should be used, as, while being burnt, dye red (*lohitapacanīyāḥ saṃbhārāḥ*)[4]. On the fuel a piece of raw clay, i.e. the *āṣāḍhā* brick (*iṣṭakā*), is placed, then the *ukhā* set down (*áva-dhā*)—according to *Kātyāyana Śrautasūtra* 16, 4, 11 'with the mouth inverted' (*nyubjā*)—, next the *viśvájyotis* bricks, i.e. another layer of raw clay put on top of it, finally the remaining space filled with fuel and kindled. The process of firing (*śrapaya-* 'water-smoking' and *pac* 'burning') is continued for more than twelve hours, because it is specifically stated that new fuel should be added in day-time only. After making, the *ukhā* is cleared from the ashes (*ud-vap*), turned over (*páryā-vartaya-*), taken up (*ud-yam*), grasped from both sides (*pári-gṛh*) and cooled (*ā-chṛd*) with goat's milk (*ajāyai páyas*) poured into it.

The chapters of the Saṃhitās of the Black Yajurveda dealing with the same matter[5] are on the whole much shorter, and MS yields almost nothing new. Unlike in the ŚB the following materials are mixed with the clay : (1) [pounded] potsherds from a deserted settlement (*armyāṇi kapālāni* KS, KpS ; *armakapālani* TS), (2) [pounded] lime-pebbles (*śarkarā*), (3) goat's hair (*ajalomá*), (4) hair of a black antelope skin (*kṛṣṇājinásya lomāni* TS). MS speaks of five materials without specifying them. KS permits five rolls of clay (*uddhi*) instead of three. MS, KS and KpS allow a span (*prādeśá*) or a cubit (*aratni*) for the diameter, or a fathom (*vyāmá* = five cubits) for the circumference, I presume, rather than for the diameter, to which KS and KpS add the remark that the size may also remain indeterminate (*áparimita*). KS and KpS leave an option of either two or four or six or eight, TS of two or four nipples (*stána*). An *ukhā* intended for black magic (*abhicārá*), should be nine-edged (*návāśri*), according to KS, KpS and TS. The firing pit is called *avaṭá* instead of *kūpa*.

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[4] For the *ukhā* see : ĀpastambaŚ. S. 16, 5, 8-9 and SatyāṣāḍhaŚ.S. 11, 1, 62 ; - for the *mahāvīra* : ĀpastambaŚ. S. 15, 3, 20; 15, 4, 2; BhāradvājaŚ. S. 11, 3, 14-16; SatyāṣāḍhaŚ. S. 24, 1, 20.

[5] MS 3, 1, 6-8 ; KS 19, 5-7 ; KpS 30, 3-5 ; TS 5, 1, 6-7.

MAHĀVIRA

KāB p. 93, 13-96, 13 and TA 5, 2, 7-5, 3, 9 :

In addition to a suitable amount of clay the following materials are required: (1) earth torn up by a boar (*varāhávihata*), (2) earth from an ant-hill (*valmīkavapā*), (3) [flowers of] the *pūtika* plant (either Basella rubra, var. cordifolia Linn. or Guilandina Bonducella Linn.), (4) goat's hair (*ajalomá*), and (5) hair of a black antelope-skin (*kṛṣṇājinásya lomāni*). They are carried by several men together into a shed (*páriśrita*) on the sacrificial ground and deposited on a gravelled (*sikatopopta*) mound (*uddhata*). Here, boiling water (*mádantīḥ*) is poured over the clay mixture and (1) [pounded] potsherds from a deserted settlement (*armakapālāni*), (2) [pounded] lime-pebbles (*śarkarā*), (3) goat's hair (*ajalomá*) as well as (4) hair of a black antelope skin (*kṛṣṇājinásya lomāni*) kneaded into it.

The *mahāvīrá* pot is fashioned by hand and a piece of bamboo (*véṇu*) without using the potter's wheel. It should be made of three rolls of clay (*ādhi, uddhi*), measure a span (*prādeśá*), a yard, a fathom, or an unspecified distance in diameter, have a vertical band applied around the neck (*rāsnā, parigrīvá*), and above the shape of a drinking cup (*upáriṣṭātpātra*), probably a spout. Having been duly fumigated (*dhūpaya-*) with horse-dung in a sunny spot (!), the *mahāvīrá* pot is fired with sprigs of Prosopis spicigera Linn. (*śamīśākhāḥ*), and, when finally freed from the ashes (*ud-vap*), cooled with goat's milk (*ajakṣīrā*).

ŚB 14, 1, 2, 9-25 :

A sufficient amount of clay is mixed with (1) earth from an ant-hill (*valmīkavapa*), (2) earth torn up by a boar (*varāhávihata*), (3) [parts of] *ādārá* plants (unidentified) and (4) goat's milk (*ajākṣīrá*). The fashioning is done by hand in an enclosed shed (*páriśrita*) on a mound (*khára*). The *māhavīrá* pot measures one span (*prādeśá*), is contracted in the middle (*mádhye saṃgṛhīta*)[6] and possesses a spout (*mukha*) of three thumb's height which is compared to a nose (*nāsikā*). Having been trimmed (*hi*) with the grass Coix barbata Roxb (*gavédhukā*) and fumigated (*dhūpaya-*) with horse-dung it is fired (*śrapaya-*) simultaneously with other vessels and raw bricks (*iṣṭakā*). Part of the fuel is placed underneath, the rest on top of the pot. When it has been freed from the ashes (*ud-vap*), it is cooled (*āchṛd*) with goat's milk (*ajāyai páyas*).

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[6] Cf. Mehendale, M.A. : ABORI vols, 48/9, 1968, 193-5.

CONCLUSIONS

Although the authors of our sources know the potter's wheel[7], they prescribe that the *ukhā* as well as the *mahāvīrá* must be hand-made, not wheel-thrown. It thus appears that the more primitive technique persisted in the ritual sphere while in secular life more advanced methods of pottery had already been adopted. Should this assumption be correct, we could pin down the transition from hand-made to wheel-thrown pottery, as far as the Aryans are concerned, to the earlier phases of Vedic times.

The clay used was mixed with various materials, some of them organic : parts of plants, hair of goats and black antelopes. These latter were, during the firing process, certainly burned, leaving the pots more or less porous. Inasmuch as the temperature obtained under open firing varies from 400° to 700° C[8] they cannot have been but ill-fired. Their sizes range from about 0.24 m to 1.0 m. in diameter at the opening, and from 0.24 m to 0.40 m in height. Particular features, useful for identification, are with the *ukhā*, the bands of clay affixed on all four sides vertically from the base of the vessels up to the horizontal belt applied at two-thirds of the total height, with nipples at their ends varying in number from two to eight. There was a possibility to fashion the *ukhā* nine-edged [instead of round or eight-edged ?] The *mahāvīrá* pot, on the other hand, was contracted in the middle, had a vertical band around the neck and possessed a nose-like spout, about 0.06 m long. Other forms of plastic decoration and all reference to painting are wanting. There may be found impressions of small pebbles on the flat bases of the *ukhā* as well as of the *mahāvīrá*, inasmuch as both the vessels were modelled on a gravel-covered mound. Firing was accomplished by the covered baking method between two layers of raw bricks in a simple open pit and, toward the end of the time under review, with materials producing red colour. Let excavators, especially at Noh (Bharatpur State, Rajasthan) and at Atranjikhera (Etah District, Uttar Pradesh) be on the look-out for ceramics of this description among their finds of plain unpainted red or ochre-coloured ware !

As everybody knows, we have absolutely no means to ever write a political history of pre-Aśokan India ; but there are hidden in Vedic tradition ample materials for a history of ancient Indian civilization. They have, until now, been exploited to a very limited extent only, and this for quite obvious reasons. The number of relevant texts is large. Reliable printed editions are, at least for some of them, not easily available, even in India. Vedic prose is difficult to understand for the ordinary Sanskritist. Last but not the least, the passages referring to a given subject are almost always very short, and for a long time had to be assembled with considerable patience by very extensive reading. Fortunately, the last-mentioned diffi-

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[7] *Kaulālacakra* : ŚB 11, 8, 1, 1 ; Cf. also MS 1, 8, 3 [118, 3] : KS 6, 3 [51, 14] ; KpS 4, 2 [45, 4].

[8] Saraswati, Baidyanath and Nab Kishore Behura, *Pottery Techniques in Peasant India*. Anthropological Survey of India. Government of India, Calcutta 13. Memoir No. 13. 1964, published on 15th October, 1966

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culty has been removed almost completely by Dr. Vishvabandhu's stupendous *Vaidikapadānukramakoṣa*[9]. Thanks to this scholar's efforts we are now in a position to utilize the very oldest written records of Aryan India as a means to check the finds unearthed by archaeologists. On the other hand, these same excavators will, in all likelihood, in a not too distant future, date the Vedic period by the radio carbon method far more exactly than has been possible until now. Provided that it be free from religious bias, the study of Vedic ritual is, therefore, of the utmost importance for a cultural history of India, and Vedic Sanskrit, far from being a dead language, has in this field a great future.

If this paper has, by using just one example, succeeded to prove this assertion, I have achieved my purpose.

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[9] 16 vol. 4°. Lahore/Hoshiarpur 1935-65.

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SANSKRIT AND ARCHAEOLOGY

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It is quite well known that the following are recognised as the sources of ancient Indian history and culture : 1. Literary sources : (*a*) Indian and (*b*) foreign and 2. Archaeological finds -inscriptions, coins, monuments, etc.[1] Archaeology[2] is generally understood to be a subject which deals with the study of antiquities. Archaeology, in brief, is the pursuit of history of man[3] studied through the material relics left by him. It " has received the aid of many sciences and has been and still is rendering services to them itself"[4]. " For the study of the past as far as Man is concerned, we have to rely on two categories of documents .... *viz.* written documents and material remains...... In the case of the written documents we have to listen to their tale before starting interpreting and criticising"[5]. For interpretation and criticism of the tale sung by the documents the archaeological techniques may also be pressed into service as a co-operative approach for better results in interpretation and criticism. As Stuart Piggot put it, this co-operative approach " can in fact amplify the strictly literary records in many directions "[6]. In this paper, it is proposed to discuss how this ' co-operative approach ' can lead to a proper interpretation of literary sources, to reliable dating, etc., especially from the Purāṇic literature, which forms the vast bulk of the Sanskrit Literature[7]. As noted above, archaeology is related to various branches of knowledge, whose help it seeks in the interpretation of the ancient finds. As H. D. Sankalia observes, there is nothing in the world which cannot be subsumed under archaeology[8].

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1. *Vide* Majumdar R.C. and Pusalker A.D. (Ed.), *The Vedic Age*, pp. 47 ff.

2. On the term ' archaeology', *vide* Bernet Kempers A.J., *Archaeology India Antiqua, J. Ph. Vogel Presentation Volume*, 1947, pp. 15 ff.

3. Sankalia H.D., *An Introduction to Archaeology*, p. 1.

4. Bernet Kempers, A.J., *op. cit.*, p. 24.

5. Bernet Kempers, A.J., *op. cit.*, p. 17.

6. Piggot Stuart, *Approach to Archaeology*, 1965 (Penguin Series Edition), p. 124.

7. *Vide* Kantawala S.G., 'The Purāṇas and Epics as Sources of Religious, Social and Cultural History of India', *Journal of the M.S. University of Baroda*, Vol. XIX, No. 1, April, 1970, pp. 45 ff.

8. Sankalia H.D., 'Archaeology and Purāṇas - Mahābhārata and Rāmāyaṇa' (in Gujarati), *Svādhyāya*, Vol. IX, No. 1, p. 91.

"Historical genealogies form one of the main characteristics of the Purāṇas"[9]. In this connection the following passage from *The Purāṇa Text of the Dynasties of the Kali Age* by F. E. Pargiter may be cited :

शक्यमानाभवद् राजा महिषीणां महीपतिः ।[10]

He translated it as follows :

"Śakyamāna was a king of Mahiṣis".[11] He has accepted the reading महिषी and has noted other variants. It may be observed that this reading does not yield a convincing sense as it stands. On the basis of the impressions of the two coins with fragmentary but complementary legends, sent by Hurmuz Kaus to V. V. Mirashi, the latter reconstructed the legend as follows by putting them, *i.e.*—

(i) रंभो सग-मान-भ and (ii) ग-मान-महम together as रंभो सगमान महसस = Skt. राज्ञः शकमानमहिसस्य, that is,

This coin is of Śaka king Māna Mahisa. In the light of the above reconstruction he proposes to emend Pargiter's text as follows :—

शकमानोऽभवद् राजा महिष्याणां महीपतिः ।

i.e. "The Śaka king Māna was the ruler of the Mahiṣya country".[12] Incidentally, it may be mentioned that one of the manuscripts of the *Vāyu Purāṇa* has a lection *mahiṣyāṇām*, which Pargiter did not accept ; perhaps it was a *lectio difficilior*. This indicates how the numismatic data can help in selecting a right lection.

In Purāṇas the historical information is often couched in mythological setting ; but when the myth is denuded with the help of field-study, it bears out important piece of information. In chapter 39 of the Kumārikākhaṇḍa, a part of the voluminous *Skānda Purāṇa*, there are the following significant lines in connection with Kumārīśvara, a temple of Śiva, situated in Cambay in the Gujarat State :

ततः कालप्रकर्षाच्च प्रासादे स्कन्दनिर्मिते ।।
जीर्णे, नव्यं स्वर्णमयं प्रासादं साऽप्यकारयत् । 169 cd., 170 ab.

i.e. She (Kumārī) caused the old temple to be new, *i.e.* the temple was renovated. A visit to Kumārīśvara reveals the fact that "the modern temple is at least five feet below the present land surface"[13]. The earlier and the later phases are discernible[14].

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[9] Mirashi V.V., "Some Purāṇic Passages corroborated by Inscriptional and Numismatic Evidence", *Purāṇa*, Volume 1, No. 1, p. 31.

Cf. also :

सर्गश्च प्रतिसर्गश्च वंशो मन्वन्तराणि च ।
वंशयानुचरितं चैव पुराणं पञ्चलक्षणम ।। *Matsya*, 53.65

[10] Pargiter F.F., *The Purāṇa Text of the Dynasties of the Kali Age*, 1962, p. 51.

[11] Pargiter F.E., *op. cit.*, p. 73.

[12] Mirashi V.V., An Ancient Śaka Dynasty of Māhiṣmatī, *Indian Historical Quarterly*, Vol. XXII, pp. 34 ff : *op. cit.*, p. 34.

In the sixth chapter of the Kumārikākhaṇḍa Nārada is shown as "desirous of settling a colony of Brahmins in a holy place"[15], situated at the Mahīsāgarasaṅgama. The phrase *Mahīsāgarasaṅgama* was interpreted as "the meeting place of the earth and the sea"[16]. But a field-study would show that this refers to the place where the river Mahī meets the ocean[17] near Cambay in the Gujarat State.

The *Matsya Purāṇa* refers to the Narmadā-Kāverī-saṅgama in chapter 189. Apparently, this appears to be absurd, because the Narmadā is a river which flows through the Madhya Pradesh and the Gujarat States, whereas the Kāverī is a renowned river of South India. But a visit to Omkareshvar in the Madhya Pradesh reveals that a small rivulet known as the Kāverī meets the Narmadā[18] and this testifies to the correctness of the statement of the Purāṇakāra.

Kālidāsa in his *Meghadūta* describes the Narmadā as :

> तस्यास्तिक्तैर्वनगजमदैर्वासितं वान्तवृष्टि-
> र्जम्बूकुञ्जप्रतिहतरयं तोयमादाय गच्छेः । 20 ab.
> (S. K. De's edn.)

i.e. the cloud is asked to proceed after taking the waters of the Narmadā with its speed impeded by the bowers of the Jambū trees.

Here the phrase जम्बूकुञ्जप्रतिहतरयम् is important. This description of the river Narmadā is taken as "a poetic effulgence"[19]. But it is not so, as pointed out by G. B. Pandya, on the authority of Narendra Bhatt who had planned a boat-expedition from Amarakantaka to Broach, that "near Handia he (*i.e.*, Narendra Bhatt) came across a spot where the boat had to be steered with the help of Jambu tree hand-grips. In this area the river broadens out and is lost in myriads of Jambu trees."[20]

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[13] Mehta R.N., 'Kaumārikākhaṇḍa—A Study', *Journal of the M.S. University of Baroda*, Vol. XIV, No. 1, p. 43.

[14] Mehta R.N., *op. cit.*, p. 43.

[15] Bedekar V.M. 'The Legend of Cirakārin in the Skanda-mahāpurāṇa and the Mahābhārata'; *Purāṇa*, Vol. IV No. 1 p. 198.

Cf. :

> अहं ब्रह्मणो वाक्याद्विप्राणां स्थानकं शुभम् ।
> दातुकामो महातीर्थे महीसागरसंगमे ॥
> स्कन्दपुराण, माहेश्वरखण्ड, कौमारिका-खण्ड, 6,9.

[16] Bedekar V.M. *op. cit.* p. 198.

[17] *Cf.* Sircar D.C., 'Mahīsāgarasaṅgama', *Purāṇa* Vol. V, No. 2, pp. 352 ff. ; Mehta R.N., 'A consideration of the Mahīsāgarasaṅgamatīrtha', *Purāṇa*, Vol. IX, No. 1, pp. 195 ff.

[18] Kantawala S.G., *Cultural History from the Matsyapurāṇa*, p. 344.

[19] Law B.C., *Historical Geography of Ancient India*, p. 324, where he refers to the *Raghuvaṃśa* 5.42-46 and observes that the Narmadā flows through the forests of Jambū and Raktamāla trees. The variant is *naktamāla*. The Raktamāla trees are referred to in the *Raghuvaṃśa* 5.42. The Jambu trees are mentioned in the *Meghadūta*. G.B. Pandya observes that B.C. Law says that "this is poetic effulgence". *Geographical Data in the Meghaduta*, (Meghadūta, M.S. University Symposia Series, 7, 1957, p. 12.)

The story of the " Destruction of Tripura " is found in several texts in Sanskrit literature[21]. The *Matsya Purāṇa* says that it was at Maheśvara on the Narmadā, where Lord Śiva contemplated the destruction of Tripura (the triple city), a prosperous city ; even the Asura women there are said to be very pious and virtuous. In the Puṣya-yoga (140.44) he discharged a *triparvan* and *triśalya* arrow (188.9) which set Tripura ablaze. Tripura is identified with modern Tewar near Jubbalpore. The ancient relics of Tripurī lie on a long narrow ridge of a mountain which has three clear-cut parts. The city's being on three parts lent it a highly significant name of Tripura or Tripurī[22].

The conquest of Tripura by Śiva may suggest the triumph of Śaivism there. Some more points from the episode may also be mentioned here. Maya had built a step-well full of nectarine water by which the dead demons were resuscitated, during the war (136.11). But Viṣṇu is said to have drunk it up (136.65) to weaken the strength of Maya. This may suggest, according to H. D. Sankalia[23], that the key water-supply was cut off forcing the enemy to submit. It is further said in the *Matsya Purāṇa* that the water-reservoirs had their water dried up in the fire-raid (188.28, 55).

The city of Tripura is said to be of gold, silver and iron (129.33). It is significant to note that the *āyasa* city is said to be on the earth[24].

The *Matsya Purāṇa* informs that *Purūravas*, the Lord of Madras, leaving the gubernatorial burden to the ministers retired to the Himalayas where the river Airāvatī (=Ravi)[25] was flowing (115.17-19). On her bank he saw a grand temple of Śeṣaśāyin Viṣṇu (119.28-35). This refers "to a magnificent temple of Viṣṇu as Śeṣaśāyin at the source of the river Ravi near Kangra "[26].

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[20] Pandya G.B., *op. cit.*, p. 12.

[21] It is traceable to the Vedic literature; vide *Taittirīya Saṃhitā*, 6.2.2.2., *Aitareya Brāhmaṇa* 2.1.1, Sankalia H.D., *op. cit.*, p. 109. The story is found with additions in the *Matsyapurāṇa*, chapters 129-140, 187-188.

[22] Mehta R.N. and Chaudhuri S.N. 'Tripurī nī Purāvastu' (in Gujarathi), *Vidyāpīṭha*, Vol, 5. No. 4, 1967, p. 15 : vide also Sankalia H.D., *op. cit.*, pp. 103 ff.

[23] Sankalia H.D., *op. cit.*, p. 108.

[24] According to H.D. Sankalia, the *pura* of *āyasa* on the earth implies that it was built in the beginning of iron age. (*op. cit.*, p. 107). One of the Tripura which fell burning on the earth is said to be known as Jvāleśvara. (vide Kantawala S.G., *op. cit.*, pp. 35-336 : Sankalia H.D., 'Purāṇas and Archaeology', *Bhavan's Journal*, vol. XIII, No. 2, Aug, 1966, pp. 167-178.

[25] Kantawala S.G., *Cultural History from the Matsyapurāṇa*, p. 298.

[26] Sharma Brajendra Nath, 'South Indian Bronzes in the National Museum', New Delhi, *East and West*, Vol. 20, No. 3, September, 1970, p. 361.

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The *Śrīmāla Purāṇa,* chapter 29, deals with the Mukulinī-māhātyma. Mukulinī devī is the family-deity of the Mukuriya Vaṇiks. The chapter narrates that a girl Pramadvarā by name, the daughter of the merchant Mahardhi, was once caught hold of by Kalīmukhī demoness and kidnapped. She cried out for rescue. On hearing this alarming cry, Plavaṅgī came to rescue with other Joginīs and killed the demoness.

Cf. :—

पीडां कर्तुमना देवी त्रिशूलं बिभ्रती करे ।
श्रुत्वा करुणमारावं कुमार्याः खेऽवलम्ब्य सा ॥ २९ ॥
श्रुत्वा कलीमुखीं देवी त्रिशूलेन हृदि क्षणात् ।
कन्यामुत्सङ्गमारोप्य सखीमध्ये समत्यजत ॥ ३० ॥

In token of the gratitude for saving her life she worshipped the goddess. In the worship, flesh was to be offered ; but it could not be done and at last her brother was ready to immolate himself. The goddess was pleased and she was worshipped by them as Mukulinīmātā. She is worshipped on the hill of Kṣemaṅkarī in Devī's temple at Śrīmāla (Bhinnamāla). Kṣemaṅkarī is a form of Maheśvarī[27]. The whole story is based on some beliefs prevalent in the Mukuriya Bania group and they have been transferred to the goddess Kṣemaṅkarī. Her form is similar to the Mahiṣamardinī-form of Kātyāyinī. This is highly significant, because the enemy is killed with the trident[28].

The Nāgarakhaṇḍa, a part of the bulky *Skanda Purāṇa,* mentions that a ruler Camatkāra by name built a fortified town one Krośa in dimension situated on a mound Raktaśṛṅga by name[29]. The whole episode refers to the township of Vadanagar in North Gujarat. The fort-wall of the town Vadanagar is made of bricks and this gives a red appearance. " This is the basis of naming the mound at Vadanagara as Raktaśṛṅga"[30]. The site-study shows that " the measurement of the fort of Camatkārapura proves the correctness of the Paurāṇic record and leaves no doubt as to the identification of the Raktaśṛṅga and Camatkārapura as the mound and town of Vadanagar."[31] The Purāṇa refers to the destruction of the town and its rebuilding. The Vadanagara-Praśasti[32] refers to the construction of the fort in 1152 A.D. during the reign of Kumārapāla (1144 A.D. to 1173 A.D.). It refers also to the repairs in 1633 A.D. By correlating the Purāṇic data with this inscriptional evidence and granting a due lapse of time to get the memory dim, so as to give a fictitious name like Camtakārapura to a town, this portion, *i.e.* the Nāgarakhaṇḍa may be assigned to the 17th century A.D.[33] This illustrates how a collation of the field-study and the textual study helps the better interpretation and understanding of the text.

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[27] Parmar Bhabhootimal Nawanji, *Cultural and Critical Study of Śrīmāla Purāṇa,* Unpublished Ph.D. Thesis, M.S. University of Baroda, 1969, pp. 35-36, 145.

[28] Mehta R.N., Personal Inteview and Discussion.

[29] Mehta R.N., 'Nāgarakhaṇḍa, A study' *Journal of the M.S. University of Baroda,* Vol.XVII, No. 1, April 1958, p. 109.

[30] Mehta R.N., *op. cit.*, p. 110.

[31] Mehta R.N., *op. cit.*, p. 110. 1 kośa = 1 kilometer approximately. *op. cit.*, p. 110.

[32] Vide *Indian Antiquary,* Vol X, p. 160; *Epigraphia Indica,* Vol. I, p. 293.

In the study of the classical texts also the co-ordinated study leads to the proper understanding and valuation of the textual data. For example, in Bāṇa's *Kādambarī* we are told that when Candrāpīḍa came near the Acchoda lake, he heard some music and going in search in the direction of that music, he came across a Śiva's temple where he saw "*caturmukhaṃ bhagavantaṃ Tryambakam*".[34] The reference to the *Caturmukha* of Śiva is very significant, as it refers to the special characteristic of the *Śiva-liṅga* of the Gupta period, *i.e.* the *Caturmukha Śivaliṅga*[35].

Thus the foregoing discussion shows that the correlated study of the literary sources and the archaeological data is fruitful in the consideration of the problem of chronology and in the better understanding and appreciation of the literary sources.

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[33] Mehta R.N., *op. cit.*, p. 111.

[34] *Kādambarī* of Bāṇabhaṭṭa (pp. 124-237, Dr. Peterson's edition) edited by P.V. Kane, 1921, p. 3.

[35] Agarwala V.S., *Kādambarī - Ek-Adhyayan* (in Hindi), p. 139. fn. 2.

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THE CONTRIBUTION OF SANSKRIT TO THE UNDERSTANDING OF THE EROTIC SCULPTURES OF KHAJURAHO

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The temples of Khajuraho marking the final efflorescence of the north Indian architectural traditions have been a subject of keen study since Cunningham published his survey-account of these temples (A.S.R. Vol. II, 1871 pp. 412-438). The temples are remarkable for their architectural grandeur, wealth of graceful, lively sculptures, and richness and variety of iconographic details. However, in recent years casual visitors and serious scholars alike have been attracted by their erotic sculptures. Various scholars in their attempt to explain the real meaning of these enigmatic scenes have put forth different theories which are either purely speculative or sadly erroneous. Sanskrit literature and inscriptions contribute to a proper understanding of at least one group of these apparently incongruous and problematical figures.

There are about thirty temples at Khajuraho of various sizes and in different stages of preservation. There is a divergence of opinion regarding the chronology of these temples. My own studies show that the Jaina temples Ghaṇṭaī and Pārśvanātha are the earliest temples at the site, other Jaina temples being contemporaries of the later Hindu temples. They are followed by the Lakṣmaṇa temple built by Yaśovarman, in the second quarter of the tenth century. Of the Hindu temples nine belong to the Vaiṣṇava sect, seven to the Śaiva, and one each to the Śākta and the Saura.

The Ghaṇṭaī temple is in ruined conditions. The Pārśvanātha temple does not show erotic sculptures, except one erotic *mithuna* in a not very conspicuous place on the northern facade of the *sanctum* proper. Though the *Vāstuśāstras* freely permit the representation of *mithunas*, the Jaina *ācāryas* and *munis* appear to have disapproved this. However, they are frequently seen on the Hindu temples, some occupying very prominent places, right from the Lakṣmaṇa temple. As at least two figures are essential in an erotic representation, such scenes require broader space and hence on the temple-walls they are seen in the broader recesses (*antarita*), the projections showing single figures, divine or of apsaras. The recesses and niches on the *śikharas* and decorative friezes on the *jagatī* (plinth) and *adhiṣṭhāna* (base) also contain scenes of this nature.

A close study suggests the following classifications of the erotic scenes on the Brahmanical temples of Khajuraho :

(i) Scenes in which the female partner is a house-wife and the male a naked and shaven-headed ascetic. Even in such other scenes of this group which comprise more than two figures the ascetic is invariably present. These scenes are prominent on the Vaiṣṇava temples. particularly on the Lakṣmaṇa.

(ii) Scenes occurring on the exterior *pradakṣiṇāpatha* wall against the *antarāla* of the Viśvanātha and Kandariyā Mahādeva temples, each of which has a number of figures. Certain elements like a supervising seated figure or use of *śīrṣāsana* by the main male figure give these scenes somewhat ritualistic or tāntric colour.

(iii) Erotic or amorous *mithunas*.

(iv) Scenes depicting indoor amorous activities of a man or a woman, as indicated by the furniture and surroundings. These scenes occur on the decorative friezes and use various erotic poses.

Most of the theories, which attempt to explain these scenes do not try to go into their contemporary background but only seek an explanaion subjectively. In one case where such an attempt has been made the representation of these erotic scenes and consequently the religious edifices which portray them have been attributed to the Kaula Kāpālika cults, which is faulty. This becomes clear when we take the help of the contemporary Candela inscriptions and contemporary and earlier Sanskrit works.

The Khajuraho inscription of Yaśovarman dated Samvat 1011 (954 A. D.) and belonging to the Lakṣmaṇa temple opens with an invocation to Vāsudeva and hails different forms of Viṣṇu in the following three verses. The Vaiṣṇavite character of the temple is further evident form the facts that (i) the *sanctum* enshrines an image of Viṣṇu in Vaikuṇṭha-form. (2) the door-way to the *sanctum* shows an image of Viṣṇu as *lalāṭa-bimba,* and (3) the Vaiṣṇava figures form the majority among the decorative sculptures. In the said inscription there is not even a single word which may show any influence of the Kaula and Kāpālika sects. These last-mentioned sects were opposed to Vedic religion and what Vedic religion stood for. They did not believe in the *varṇāśramadharma* and the Vedic rituals and *saṁskāras* and the Vedic rituals and *samskāras* had no significance for them. The Sanskrit epigraphs show that the Candela kings practised the customs of the Kṛta age (*kṛta-kṛtayugācāra-puṇyasthitīnāṁ*), were promulgators of the Vedic religion and well-wishers of the cow and the Brāhmaṇas. The concluding verse of the inscription is worth quoting in this regard :

Pātādbhūmipatiḥ pṛthvīṁ trayīdharmaḥ pravardhatām |
Nandantu godvijanmānaḥ prajā prāpnotu nirvṛtim ||

Being the earliest Hindu temple at the site, the question of its following a tradition in this regard does not arise. Thus the erotic sculptures on the Lakṣmaṇa temple lose all their supposed Kaula-Kāpālika significance.

The male ascetic participant in the erotic scenes of the first group is represented as completely naked, shaven-headed and clean-shaved. He does not wear any

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cloth, and beard, moustaches or *jaṭās*. He carries two attributes—a thin ro stick with a knob at the farther end and a water-pot, the latter sometimes suspended from one of his shoulders. A *svastika* mark is also carved on his chest. The association of these scenes with any religious sect or the proper understanding of the objective behind their representation obviously depends on the correct identification of this ascetic. In the vulgarised Kaula cult partaking of *pañcāmṛta* or *pañcamakāras* and participation of *veśyākumārikās* was enjoined ; and according to Kāpālikas deliverance lay in unrestricted enjoyment of the senses, particularly women and they constantly lived with female companions called *Kapālavanitās*. But this does not mean that any ascetic shown engaged in the lascivious activities is to be identified with a Kaula or Kāpālika ascetic simply on the basis of this casual and superficial resemblance. Sanskrit literature provides us with significant information helpful in this regard. Kṣemendra, in the second *parihāsa* of the *Narmamālā*, describes a Kaula teacher as having 'a little knot, arranged out of his *śikhā* alone near the ear-root (*karṇamūlaśikhāmātragrathitasvalpajūṭikaḥ*) and thin beard (*viralaśmaśru*). He is also said to wear a *yogapaṭṭa* across his chest. We believe that both the sculptor and the poet have faithfully recorded their observations. If this is so, the ascetics shown as male participants in the erotic scenes of the first group cannot be identified with the Kaulas. Similarly they are also not identifiable with the Kāpālikas who are differently portrayed in the Sanskrit works. According to the *Āgamaprāmāṇya* of Yāmunācārya the Kāpālikas 'wear the sacred thread, crest jewel, ornaments for ear and neck, carry a human skull, a club, and their body is smeared with ashes'. The club is also mentioned in the *Kathāsaritsāgara*. The *Prabodhacandrodaya* describes Somasiddhāntin, a Kāpālika, as wearing a garland of human bones as an ornament (*narāsthimālākṛtacārubhūṣaṇaḥ*) and taking his food in a human skull (*nṛkapālabhojanaḥ*) ; at another place his necklace is said to be made of human bones and skulls (*narāsthimuṇḍamālādhārakaḥ*). Probably they carried also a word. The description of a Kāpālika by Daṇḍin is similar. In the seventh *ucchvāsa* of the Uttarapīṭhikā of the *Daśakumāracarita* the following epithets are applied to him : (i) *narāsthiśakalaracitālaṅkārākrāntakāya* i.e., whose body is covered with ornaments made of the pieces of human bones, (ii) *dahanadagdhakāṣṭhaniṣṭhāṅgārarajaḥkṛtāṅgarāga* i.e., who has made the ashes effecting from the wood consumed by (funeral) fire, as cosmetics to his body, and (iii) *taḍillatākārajaṭādharaḥ*, having long (untied) hair resembling the streaks of lightning. It becomes evident that the Kāpālikas had long (matted) hair, applied ashes to their body and adorned their person with ornaments made of bones and skulls. It is clear, therefore, that the ascetics in these compositions are not the well-known Kaulas and Kāpālikas of the Śaiva sects. But notwithstanding the identification of this ascetic, the fact that the erotic scenes in which they appear are found not only on the Śaiva and Śākta temples but also on the Vaiṣṇava ones, and that too at conspicuous places, is against the affiliation of such scenes, and consequently of the temples on which they appear and their royal builders, with the Kaula-Kāpālika faith.

It is clearly inferred from *Prabodhacandrodaya* that due to the Vedic teachers' intellecutal decline and moral degradaction and their scornful behaviour towards

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the masses, the Vedic influence on the people had suffered a severe set-back. With the rapid loosening of the Vedic hold on the masses, sprang up numerous sects whose teachers, hailing from the lower strata of society disregarded and ridiculed Vedic sacrifices and other rites, and with the sole objective of bringing people within their fold, enjoined all worldly enjoyments in their essentially non-Vedic doctrines. This religious degeneration appears to have set in a few centuries before the time of the author of the *Prabodhacandrodaya* and the Kaula Yāga described in the *Narmamālā* presents a cross-section of the contemporary religious life. The Buddhism, as evident from the *Prajñopāyaviniścayasiddhi* and *Jñānasiddhi*, two Vajrayāna works assignable to *circa* 700 A.D., had become tāntric and esoteric quite early and prescribed the partaking of *pradīpa* and *pañcāmṛta* and constant company of women regarded as the different forms of Prajñāpāramitā on earth. The initiated is advised to enjoy to his liking without the slightest hesitation and to take any food or drink. The universe is created by Vajranātha for the enjoyment of his followers and hence he is cautioned to follow his desire in actions because, if he acts otherwise, he can never attain success. In such an atmosphere the Jainism also does not appear to have remained unscathed. The Jainas also criticised the caste system and the rites like *śrāddha*. The popular Hindu beliefs like Sun-worship, bath during eclipses, giving away money on *saṁkrānti* days, the morning and evening-ablutions, fire-worship, the worship of edifices, ceremonial bathing in rivers and the ocean were bitterly criticised by them and condemned as stupid customs. They also ridiculed the Brahmanical gods Brahmā, Viṣṇu, Śiva and Kṛṣṇa. It was part of Jaina propaganda to hold up the tenets of other faiths to ridicule and dilate on the excellence of Jainism. There was a tendency to show considerable latitude to those converts who were unable to forego completely their former customs and beliefs since total loss of a new adherent (was) by no means desirable. The Jaina teachers also probably failed to maintain the purity of their character. Somadeva's advice to the householders is an indicator in this regard. He says: 'It is useless to test the purity of monks for the purpose of giving them food : Whether they are good or bad, the householder is purified by the mere act of giving. Licentiousness of the Jaina monks is evident in the *Prabodhacandrodaya* wherein a Jaina Kṣapaṇaka explains to his disciples the method of service to the teachers thus: "salute his feet from a distance, serve sweet dishes with due honour and if the monks enjoy the company of your wives you should not entertain the impure feeling of envy (or be impatient)".

> Dūre caraṇapraṇāmaḥ kṛtasatkāram ca bhojanam miṣṭam |
> Īrṣyāmalaṁ na kāryaṁ ṛṣīṇām dārān ramamāṇānām ||

Against this background, one need not turn towards the Kaulas or Kāpālikas only for the identification of this ascetic, and the identification has to be made on very definite grounds. Two of the characteristics of these ascetic figures, (*a*) nakedness and (*b*) shaven-headedness squarely tally with those of the Digambara Jaina monks. The svastika mark on their chest lends further colour to this correspondence. The water-pot being carried by these ascetics is a non-denominative attribute. But the remaining attribute, the stick with a knob resembling the fruit of a lotus flower at one end, appears to be nothing else than the *picchikā*, a very regular attribute of a Digambara ascetic as known from Sanskrit literature. Bāṇa in the fifth Ucchvāsa of the *Harṣacarita* makes peacock-feathers a mark of the naked Digambara ascetic (śikhipicchalāñchano nagnāṭakaḥ). The *Prabodhacandrodaya* explicitly styles the Jaina Kṣapaṇaka as one holding a bunch of peacock-feathers in one hand (śikhiśikhaṇḍapicchikāhasta). That the peacock-feathers were invariably carried by the Digambara monks is also inferred from a verse of the Khajuraho inscription of Dhaṅga dated Vik. Sam. 1059 (1002 A.D.), The identification of these ascetics with the Digambara monks is established beyond any doubt on the basis of two more facts. The first is that one of the scenes on the southern facade of the Lakṣmaṇa temple wherein this ascetic is seen in coition with a stooping woman contains a one-line inscription as label which reads *Śrī Sādhunandi khapanaka*. The second fact is that the representation of the Digambara monks shown seated with folded hands flanking a seated Jina in dhyānamudrā on the lintel of the maṇḍapa doorway of the Jaina temple Pārśvanātha is identical with the figures of the ascetic together with the two attributes.

No doubt such an identification goes against the established notion that a religious amity existed at Khajuraho as manifest from the temples belonging to different sects standing side by side. But there is little scope to doubt the present identification. A further objective study will prove the notion to be false. It may be inferred from the contemporary drama *Prabodhacandrodaya* that the Hindu intellectuals and elite felt concerned with the prevailing state of the society and realised the need for forgetting mutual sectarian rivalry and uniting themselves against the common impending danger. Besides they were equally alive and active in criticising their opponents. One of the Jaina practices which provoked adverse comments of the Hindu and was defended by the Jaina writers was the nudity of the Digambara monks. In the contemporary society in which considerable sensualism prevailed, the disapproval of the nudity might have been guided by social and moral considerations. A scene on the southern facade of the Devī Jagadambā temple shows the vehemence of a Hindu ascetic against the practice of the Digambara monks roaming naked in the society. The scene represents a Brahmanical, probably Bhāgavata ascetic, wearing *upavīta, kaupīna* and *rudrākṣamālā* round the neck and having beard, moustaches and jaṭās, holding *penis erectus* of a Jaina *Kṣapaṇaka* in his left hand and ready to strike him a blow with his upraised right hand; the Digambara ascetic is shown with folded hands as if begging his pardon. The *penis erectus* of the Kṣapaṇaka may be suggestive of the lack of his control over the senses. There are other scenes which betray similar emotions.

Thus it will appear that neither the builders of these temples nor the sects to which these temples belong, approved licentiousness of character. These scenes portrayed on the temples may aptly be termed as *stone posters* exposing and publicising the vile acts of the hypocritic Digambara monks with a view, perhaps, to rouse a popular disapproval of the unhealthy Digambara practice of roaming naked in the society.

As noted above, the scenes of the second group occur on the facades of the Viśvanātha and Kandariyā Mahādeva temples. The number of participants in them is always more than two, and the male figures appear to be householders wearing long hair combed and gracefully arranged in a chignon behind the head, and ornaments. To have a long hair was an aristocratic fashion in ancient India.

The lowest panel on the southern facade of the Viśvanātha temple comprises one man and three women all standing as main figures, the male being shown in union with the woman in the centre, while the other two women in coquetish langour are portrayed, one on either side, with one of the hands placed on the face and other on the hip, hiding nudity in one case. In the lower field the scene shows two more figures ; a corpulent figure seated cross-legged and supporting the bulk of his body by his left hand placed straight on the left knee in the centre, and a dancing dwarf on the right. The seated figure looks like a teacher conducting and supervising some religious rite. A somewhat similar scene is shown on the northern facade of the Lakṣmaṇa temple. In one of the scenes on the Kandariyā Mahādeva temple the male participant is shown in *śīrṣāsana.* The main female figure with whom he is in coition is carved seated above him with her hands placed on the shoulders of two other women standing on either side giving support to the couple with one hand while their nudity is covered by the man who has placed his hands on their pelvises. The *Śīrṣāsana* gives a Yogic or Tāntric colour to this scene.

The scenes of this group remain still enigmatic. As suggested above, they seem to have some religious significance, and, in themselves, may represent some aspect of Yogic Tāntric rituals. One is reminded of two Kaula and Vajrayānist rituals in this context, the *raticakra,* the final phase of the Kaula yāga, described by Kṣemendra in the *Narmamālā* and the *Prajñopāya-dīkṣā* of the Vajrayānists, detailed in the third chapter of the *Prajñopāyaviniścayasiddhi.* At one place, a Buddhist disciple is enjoined to take the help of five women in an esoteric practice which shows some correspondence with the scene on the Kandariyā Mahādeva temple. Nevertheless, there seems no reason to find in these scenes any evidence of the cult-affiliation of the temple or to associate them with the religious leanings of the Candela kings. The Viśvanātha temple was built by the Candela King Dhaṅga, an inscription of whom referring to the temple has survived. The inscription also mentions that Dhaṅga had made munificent gifts to Brāhmaṇas of pure lineage who were devoted to their six-fold duties (*ṣaṭkarmābhiratāḥ*) and had turned smoky due to daily performance of *yajñas* (*prārabdhādhvaradhūmadhūmra-vapuṣah*). This and other contents of the inscription show that, like his father Yaśovarman, Dhaṅga was also, perhaps, a patron of Vedic religion or at least he was not of non-Vedic persuasion. It is quite likely, therefore, that scenes of this type are displayed with the same objective as those of the first group. In other words, the purpose of these scenes on the temple-walls also was to exhibit and thus expose the ideologies and practices which were considered of aberrant and anti-social nature.

The *mithunas* have a long and continuous history in Indian art, their representations being found in the early Buddhist art of the centuries before Christ. It remains a favourite *motif* in the subsequent Buddhist and Brahmanical art. Historically the erotic *mithuna* represents the final stage of evolution of the originally dispassionate one, the intermediary stages being clearly noticeable in the art of the intervening periods. The architectural texts clearly enjoin their representation on temples.

The scenes of the fourth group seems to have been portrayed with a view to imparting erotic knowledge to young folk. In this context two things have to be kept in mind. First, *kāma* has been regarded in ancient India as a *puruṣārtha* and second, the temple was not only a place of worship for the ascetic and the old but an institution performing various social duties and a place of recreation, which is also evident from the considerations kept in mind while selecting a site for the temple. These are detailed almost in each important architectural text. There are some other scenes which appear to have been represented for the sake of fun. They may be regarded as general satirical caricatures for amusing non-serious visitors.

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SANSKRIT AND EPIGRAPHY

Dr. Bahadur Chand Chhabra, *Ootacamund*

Sanskrit is Sanskrit, of course; but what is epigraphy? Epigraphy is a pedantic term for inscriptions in general, or, say, study of old inscriptions. An epigraph is a writing incised or engraved on a hard substance, stone, metal, wood, bone, ivory and so forth. Again, the term epigraph usually applies to an old writing of this nature, having some historical importance. An epigraph is different from a manuscript which signifies an old writing on palm-leaf, birch-bark, paper or the like. Besides, a manuscript may be a hundredth copy of an original writing; but an epigraph is always a writing in the original. In an epigraph there never is a question of an addition to, an alteration of, or an interpolation into the original text, whereas a manuscript is subject to all these. Hence an epigraph is considered to be much more reliable and valuable as an authentic source of history than a manuscript.

Epigraphy, again, is a comprehensive term which includes in itself quite a few other related studies such as sigillography or study of seals, numismatology or numismatics or study of coins, palaeography or study of various old scripts, calligraphy or study of different styles and modes of hand-writing, and orthography or study of spellings used in a particular epigraph-one and the same word may be spelt differently by different scribes, as, for instance, Aiyar, Ayyar and Iyer. All these play a significant role in epigraphy or study of old inscriptions. And an epigraphist is one who is an expert in deciphering old inscriptions and interpreting their contents as correctly as is possible, pointing out at the same time peculiarities of their scripts, styles and spellings, all with a view to deducing historical facts therefrom, which, in turn, either fit in with the known history, add to it, alter it, or altogether reveal a new history.

We shall presently see how epigraphy in India constitutes a vital part of Sanskrit literature, not only on the historical side, but on the poeticl side as well, quite unsuspected and unexpected by Sanskritists in general. The number of Sanskrit inscriptions, both early and comparatively late, discovered within India and abroad, that lend themselves to such studies, runs literally into thousands. And the variety they present as to their contents is unsurpassed in the world. Above all, epigraphy in India has proved to be the very backbone of history, especially of the early history of India.

Sanskrit has served for centuries as the greatest of unifying factors for the people of India as one nation. India comprises many regions and tracts, each one of which differs from the rest in the matter of climate, customs, costumes, traditions, food-habits, dialects and even physical features, not to speak of religious practices and popular beliefs. In spite of this apparent diversity, there is and has all along been a unity, an underlying oneness, by virtue of which all the residents of the different states and regions concerned constitute but one Indian nation.

And this wonderful unity ultimately rests on Sanskrit alone. Sanskrit is the one common bond that unites all the diverse elements of India into one nation, culturally speaking. And when we talk of Sanskrit, we mean both Sanskrit language and Sanskrit literature. It needs no demonstration that all the different languages and dialects spoken throughout the length and the breadth of India owe their existence to Sanskrit. If they are not directly derived from Sanskrit, as in the case of some of the major languages of South India of Dravidian origin, they are greatly influenced by Sanskrit. Even in the context of the present-day movement of development and enrichment of regional languages of India, Sanskrit is resorted to and is serving as foster-mother.

As for Sanskrit literature, it is admittedly the foremost repository of Indian culture. If one wants to know the salient and essential features of Indian culture, one has to turn to Sanskrit literature. Roots of all India's schools of philosophy, sects and shades, of religion, social sciences, arts, crafts, vocations, statecraft, trade, commerce, in short, whatever constitutes a culture, are embedded in Sanskrit literature which, in the course of centuries, has grown into a shoreless ocean. Epigraphy in India is a veritable sea within this vast ocean.

While those generally acquainted with various branches of Sanskrit literature are, as indicated above, mostly unaware of the precise role of epigraphy in India, there are others who know archaeology and epigraphy but are ignorant of Sanskrit. Only those who are well grounded in Sanskrit and also know something of general archaeology, specially of epigraphy, sigillography and numismatology, can really appreciate the great contribution Sanskrit has made through epigraphy, particularly to revealing India's past glory, the wonder that was India. Such a one was Prof. Dr. Franz Kielhorn, a German savant, a great Sanskritist and a great epigraphist, to name but one of the galaxy. The combination of Sanskrit and epigraphy is indeed rare, but the first century and a half had produced quite a galaxy of them, hailing, to begin with, from Europe, notably from Germany, followed by those from India and elsewhere. The pioneers in the field took pains and did really a marvellous work. Think of James Prinsep, the then Mint Master of Calcutta, who first succeeded in deciphering the long-forgotten Brāhmī script, thereby truly laying the foundation of Indian epigraphy.

Much more than serving as a unifying factor Sanskrit has served as a carrier or vehicle of culture, disseminating Indo-Aryan culture, the great and complex culture of India, call it Hindu, Indian or whatever you please, in the far-flung lands and islands outside India proper, covering more than the world. And it is in this sphere that epigraphy, rather than any other branch of Sanskrit literature, tells us the most exciting, wonderful and fascinating tales of adventure and enterprise, dash, daring and faith. Thousands of early and classical Sanskrit inscriptions found engraved on rocks, pillars, slabs and what not, within India as well as outside India, especially in the countries of South-East Asia, are a concrete witness to the cultural intercourse India maintained for centuries with the outside world and of the expansion of Indo-Aryan culture, in all its ramifications, in those foreign regions on earth.

Foundations of the edifice of authentic history of India was laid about a century and a half ago when, thanks to the then British overlords, monumental remains scatterd all over India, till then neglected and uncared for, began to receive proper attention, resulting in due course in the establishment of a regular Archaeological Survey of India under the Government of India, which continues to do good work to this day. Rocks and pillars, railings and walls, pedestals and pavements, bearing mysterious inscriptions on them, naturally figured most prominently in these monumental remains everywhere, exciting wonder and curiosity. This, as indicated above, gave rise to the science of epigraphy. And most of what we know at present by way of India's past history is undoubtedly a gift of this epigraphy.

Aśoka, for instance, would have remained a mythical figure for us but for his edicts engraved on rocks and pillars, found in great numbers in almost every part of India. These lithic records, caused to be engraved by the Mauryan Emperor Aśoka for the benefit of his subjects, are, by the way, among the very first to attract the attention of the scholarly world. In fact, the decipherable epigraphy in India begins practically with Aśoka's rock and pillar edicts. I say decipherable because we are at present faced with hundreds of what are called Harappan seals that are twice as old as Aśoka's inscriptions and the writings on these seals remain an enigma to this day. Scholars, both Indian and foreign, are diligently busy, every one in his or her own way, at unravelling the mystery. Some claim to have succeeded in doing that. Yet practically, nobody has hit the nail on the head.

The language of Aśoka's edicts is, however, not Sanskrit ,but Prakrit or Pali, which was obviously the spoken language in his empire, at least in the eastern regions thereof. As a matter of fact, remarkably enough, all the earliest inscriptions discovered in India so far are in Prakrit. Sanskrit makes its appearance for the first time in the Śuṅga period i.e., about the second century before Christ. For the next three or four centuries the epigraphical records for the most part continue to be in Prakrit or local dialects, all derived from or akin to Sanskrit. The first notable inscription in good grammatical Sanskrit is perhaps the one of the Śaka king Rudradāman, engraved on the same rock that contains a set of Aśoka's edicts as well as a later inscription in Sanskrit belonging to the Gupta monarch Skandagupta. This famous rock is at Junagadh in Gujarat. The three inscriptions on the Junagadh rock, just noticed, it may be pointed out, hail from three different

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periods : Aśoka's, 3rd century B.C.; Rudradāman's, 2nd century A.D. and Skandagupta's, 5th century A. D.

It is not the purpose of this paper to give details of the contribution that epigraphy has made to historiography. That may cover volumes. Suffice it to say that it has brought to light many important ruling dynasties otherwise gone into oblivion like the Pallavas in the south, for instance ; added considerably to the histories known from other sources like literature and traditions; rectified certain wrong notions that had gained ground ; and in certain cases confirmed the little known facts by shedding fresh light on them. Sanskrit has been the language used in most of the inscriptions from, say, the Gupta period till the late medieval period. Gupta period is known to be the Golden Period of Indian history because of the artistic achievements and prosperity India had reached then. The same is reflected in the inscriptions of that period as well.

We have earlier stated that epigraphy in India is a veritable sea within the vast ocean of Sanskrit 'literature. The term 'literature' is commonly understood as applying to poetic compositions, in verse, in prose, or in prose and verse mixed, exhibiting flights of imagination and abounding in figures of speech. Judged from this point of view too Sanskrit epigraphy offers a tremendous lot that may be news even to the Sanskritists themselves, generally speaking. Where is the place, one may question in all seriousness, for *belles-lettres* in such matter-of-fact documents as inscriptions chiefly are ? These serve history ; and history has no room for poetry. Well, this may hold good elsewhere, but not in India. The Indian genius has all along dragged in poetry where poetry is least expected. No matter what the theme — arithmetic or architecture, law or religion, medicine or metaphysics — avenues of elevated expression, at once instructive and entertaining, are sought. In order to drive home a point, an Indian writer or speaker freely employs fancies, and hyperboles, similes and metaphor , and a host of other figures of speech, that hit the mark and radiate joy in the bargain. How intriguing, for instance, is the physician who, in adverting to the beneficial effects of the use of dry nuts of myrobalan, declares :

yasya mātā gṛhe nāsti tasya mātā harītakī |
kadācit kupyate mātā nodarasthā harītakī ||

'To one who has no mother at home, *harītakī* is mother. Mother may, on occasion get angry, but never does *harītakī* in the stomach flare up.'

Let us have another example. We have in the *Bible* : "In all thy ways acknowledge Him, and He shall make straight thy path" (Proverbs, III.6). This simple and direct advice has been tendered in an ornate fashion independently of course, by an ancient Indian theologian, as follows :

yadā carmavad ākāśaṁ veṣṭayiṣyanti mānavāḥ |
tadā devamavijñāya duḥkhasyānto bhaviṣyati ||

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'When people are able to roll up the sky like a parchment, then will it be possible to get rid of misery without even knowing God !'

This indirect and suggestive way of putting a thing is characteristic of Sanskrit rhetoricians. It is supposed to add elegance to emphasis.

When poetry can thrive well in the realms to which it is exotic, so to say, how much more luxuriantly could it not flourish in the fields in which it is more or less indigenous ? And Indian epigraphy has surely been one such field. It provided ample scope for *belles-lettres*. In invoking the blessings of his favourite deity, in extolling his patron's ancestry, in recounting the exploits of his hero, in describing a temple built by his master, or in a like situation, a writer with a poetic bent of mind would find sufficient excuse for loosening the reins of his imagination. The authors of *praśastis* on stone and of *śāsanas* on copper plates were thus not mere recorders of facts. They claimed to be poets, men of aesthetic taste and of varied experience. And mostly such claims are justifiable. The compositions of such persons deserve to be appraised as poems *cum* records, and not as mere records.

There are hundreds of inscriptions, known as *praśastis* and *śāsanas*, which contain excellent poetry in Sanskrit. But it has remained obscure for centuries until recently. Thanks to archaeological discoveries, literary compositions of considerable poetic merit have been discovered and are being discovered even today. Since they are, in general, mostly handled by archaeologists and epigraphists and utilized for the purpose of historiography, their contents have not been known to the Sanskrit Pandits. Some of the scholars have tried to draw attention to the existence of inscriptional poetry in Sanskrit, but that has not helped much.

When in 1888 Mr. John Faithfull Fleet published his edition of the Gupta Inscriptions,[1] it attracted notice of the well-known German Indologist, Dr. George Bühler. He was impressed by the poetic excellence of the very first inscription of Fleet's volume, namely, Hariṣeṇa's *praśasti* of Samudragupta. This prompted him to write a comprehensive essay which was published in 1889-1890 under the title of *Die Indischen Inschriften und des Alter der indischen Kunstpoesie* in the *Sitzungsberichte* of the Vienna Academy. Bühler's original German essay was later translated into English by Prof. V. S. Ghate of Poona, which appeared in 1913 in the *Indian Antiquary*, Vol. XLII, in six instalments. Subsequently several other scholars have written on the subject of inscriptional poetry in Sanskrit, but still it remains to be known more widely. The Sahitya Akademi desired the present writer to compile an anthology of inscriptional poetry. In 1964 it was published under the title of *Abhilekhasaṁgraha* in the Sahitya Ratnakosha Series of the Sahitya Akademi. Even this anthology does not do full justice to the subject.

Bühler selected as many as eighteen inscriptions from Fleet's Gupta-volume as possessing literary merit. In his essay cited above he subjected them to a very

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[1] *Corpus Inscriptionum Indiçarum*, Vol. III.

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thorough analysis and brought out their relative worth as poetry. In that essay he also considered the famous Junagadh rock inscription of Rudradāman and the Nasik cave inscription of Siri-Puḷumāyi, both of which are excellent examples of poetic prose in that early period, in a way, the forerunners of more elaborate compositions of this nature by Bāṇa and Daṇḍin in their *Kādambarī* and *Daśakumāra-carita* respectively. It may, however, be pointed out that the Nasik cave inscription is in Prakrit, though it follows the same *kāvya* style as in later *gadya-kāvyas*. Bühler in his evaluation of the inscriptional poetry has been a little over-enthusiastic inasmuch as he has shown partiality in his judgment. In drawing comparisons, he has been a bit too harsh on Vatsabhaṭṭi, author of the Mandasor *praśasti*[2], whom he describes as a 'versifier perhaps learned but clumsy and little gifted.' He makes further remarks about him, which are not very charitable. He says slanderingly that "he was not ashamed of making money by composing a piece of poetry occasionally, even when such a low class of people as the silk-weavers required his services."[3] His calling the silk-weavers of Daśapura as a low class people is entirely uncalled for in the given context and sounds highbrow. As against Vatsabhaṭṭi, Hariṣeṇa, author of the Allahabad *praśasti* of Samudragupta,[4] is praised to the skies by Bühler. He went into raptures over the verse in which Samudragupta was ordained by his father to be his successor.' Commenting on it, Bühler says : "This verse is one of the best productions the Indians have given us, in the domain of miniature-portraits, which is their forte." Let us quote the specific verse here :

ehy=eh=īty=upagūhya bhāva-piśunair-utkarṇitai romabhiḥ
sabhyeṣ=ūchchhvasiteṣu tulya-kulaja-mlān-ānan-odvīkṣitaḥ |
sneha-vyālulitena bāṣpa-guruṇā tattv-ekṣiṇā cakṣuṣā
yaḥ pitr=ābhihito nirīkṣya nikhilāṁ pāhi tvam=urvīm=iti ||[5]

While Bühler's treatment has been meagre from a literary historian's point of view, there have been other scholars who have viewed the subject more from an aesthetic angle. Kielhorn, for instance, while editing the Aihole inscription of Pulikeśin II, remarks : "Important as this inscription is as an historical document, to myself it seems almost more interesting from a literary point of view."[6]

We may conclude our essay by quoting a few more verses, taken at random, from certain epigraphs by way of illustration.

śrīmān dātā kṛtajño narapatir=asamo yaḥ purā Tārumāyām
nāmnā śrī-Pūrṇavarmā pracura-ripu-śar-ābhedya-vikhyāta-varmā |

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[2] *Ibid*, pp. 81-4.

[3] *Indian Antiquary*, Vol. XLII, p. 147.

[4] *CII*. Vol. III, pp. 1 ff

[5] *Abhilekhasaṁgraha*, pp. xii and 2.

[6] *Epigraphia Indica*, Vol. VI, p. 3.

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tasy=edaṁ pāda-bimba-dvayam=ari-nagarotsādane nitya-dakṣaṁ
bhaktānām yan=nripāṇāṁ bhavati sukha-karaṁ śalya-bhūtaṁ ripūṇām ||[7]

phaṇa-maṇi·guru-bhār-ākrānti-dūr-āvanarmrāṁ
sthagayati rucim=indor=maṇḍalam yasya mūrdhnām |
sa śirasi vinibadhnan randhriṇīm=asthi-mālāṁ
sṛjatu bhavasṛjo vaḥ kleśa-bhaṅgaṁ bhujaṅgaḥ ||[8]

Īśāneśvara-kośam saṁsthāpya yathā-vidhi sva-bhakti-vaśāt |
śrīmān Prakāśadharmo mukuṭam Bhadreśvarāy=ādāt ||[9]

tasmin dvīpe Yav-ākhye Puruṣa-pada-mahālakṣma-bhūte praśaste
rāj=ogr-odagra-janmā prathita-pṛthu-yaśāḥ sāma-dānena samyak |
śāstā sarva-prajānām janaka iva śiśor=janmato vatsalatvāt
sann-ākhyaḥ sannat-ārir=Manur=iva suciraṁ pāti dharmeṇa pṛthvīm ||[10]

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[7] *Abhilekhasaṁgraha*, p. 3. Description of King Pūrṇavarman in his Jambu (West Java) rock inscription, 4th century A.D.

[8] *Ibid.*, p. 13. Homage to Śiva in Mandasor inscription, 6th century A.D.

[9] *Ibid.*, p. 23. Consecration of Crest and Crown of Śiva. My-son (Viet-nam) Stelae inscription of Vikrāntavarman I, Śaka 609=A.D. 687.

[10] *Ibid.*, p. 22. Description of King Sanna in his Changal (Central Java) inscription, A.D. 732.

SANSKRIT AND INSCRIPTIONS—CENTRAL INDIA

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Epigraphy is important not only for the part played by it in unveiling the history and culture of a country shrouded in the hoary past, but also for the literary inheritance preserved in it. The history of the origin and development of Sanskrit *Kāvyas* goes a long way to establish the inter-relationship between Epigraphy and Sanskrit Literature. Both have influenced each other. In this paper is presented a study of two Sanskrit Inscriptions of Mandasor in Central India from a literary point of view.

Sanskrit Inscriptions belonging to Central India and some other parts which now come in the State of Madhya Pradesh, which have come to light and have been edited by scholars are—

1. Eran Stone Pillar Inscription of Samudragupta (c.335-76 A.D.)
2. Udayagiri Cave Inscription of Candragupta II (401 A.D.)
3. Sanchi Stone Inscription of Candragupta II (412 A.D.)
4. Tumain Fragmentary Inscriptions of the time of Kumāragupta I and Ghaṭotkacagupta (435-36 A.D.).
5. Mandasor Stone Inscription mentioning Kumāragupta I and Bandhuvarman (436 and 473 A.D.).
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11. Mandasor Stone Inscription of Yaśodharman *alias* Viṣṇuvardhana (532 A.D.).
12. Mandasor Stone Pillar Inscription of Yaśodharman (c. 525-35 A.D.).
13. Eran Stone Boar Inscription of the time of Toramāṇa (c. 500-15 A.D.).
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15. Ganj Inscription (of Vyāghra) of the time of Pṛthvisena II.
16. Pipardula Copper-plate Inscription of Narendra.
17. Gujarra Minor Rock Edict I of Asoka.

Sanskrit Inscriptions of Central India which have been studied in the present article are—

1. Mandasor Stone Inscription of Yaśodharman *alias* Viṣṇuvardhana (532 A.D.).
2. Mandasor Stone Pillar Inscription of Yaśodharman (c. 525-35 A.D.).

We take up the Mandasor Stone Pillar Inscription of Yaśodharman *alias* Viṣṇuvardhana first. From the title of the Inscription given by D. C. Sircar[1] and R. B. Pandey[2] it may be inferred that the Inscription is connected with a King Yaśodharman, who was also known as Viṣṇuvardhana. J. F. Fleet, however, gives a little different caption to the above Inscription, *viz.* Mandasor Stone Inscription of Yaśodharman and Viṣṇuvardhana. It appears from this caption that the Inscription refers to two Kings, Yaśodharman and Viṣṇuvardhana. The verse which led to this controversy reads as—

Ājau jitī vijayate jagatīm punaśca
Śrī-Viṣṇuvardhana - narādhipatiḥ sa eva |
prakhyāta aulikara-lāñchana ātmavaṁśo
yenoditodita-padaṁ gamito garīyaḥ || v.6

The use of the word 'the same' ('*sa eva*') in this verse is somewhat trickish While translating the verse Fleet observes regarding the expression 'the same' ('*sa eva*') that 'this expression looks at first sight as if Yaśodharman and Viṣṇuvardhana were one and the same person. But the general structure of this verse, as well as the use of the two distinct titles '*janendra*' and '*narādhipati*' and of the expression '*ātmavaṁśo*', shows that this is not the case. "This same" simply means "the reigning king", in whose time and territory the inscription is written.[3] This contention of Fleet seems untenable on certain grounds. Firstly, how the expression "this same" ('*sa eva*') came to mean the ruling King of the time is inexplicable. Secondly, if the aim of the poet was to glorify the ruling King Viṣṇuvardhana why would he have eulogised the King Yaśodharman is also not very clear. Thirdly, to take '*janendra*' and '*narādhipati*' as two different titles is also not very logical. Fleet has tried to distinguish the two by taking the term '*janendra*' to mean 'a lord of people or tribe' and the term '*narādhipati*' to mean 'a chief ruler of men'[4]. This distinction does not seem to be proper. Both these terms mean one and the same thing, *i.e.*, 'lord of people', and thus these were

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[1] *Select Inscriptions*, p. 411.

[2] *Historical and Literary Inscriptions*, p. 131.

[3] *Corpus Inscriptionum Indicarum*. Vol. III, p. 155 f.n. 5.

[4] *Ibid*, p. 155, f.n. 2 and 3.

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not two titles but only one used for one and the same King who was known as Yaśodharman *alias* Viṣṇuvardhana. Dr. Sircar's remarks on this point also support the same view. Observed Dr. Sircar : 'In interpreting verses 5 and 6 of the record, Fleet suggests that Yaśodharman and Viṣṇuvardhana were not identical and that the latter was a feudatory of the former. He thinks that Yaśodharman was a '*janendra*' = tribal ruler, and Viṣṇuvardhana a '*narādhipati*' = king of men. But both the words mean 'a king' and the context shows that they were used for the sake of alliteration. It should further be noted that Yaśodharman is also called '*samrāṭ*' (the same as '*rājadhirāja-parameśvara*' of this record)......The passage '*sa eva*', Viṣṇuvardhana's title '*rājādhirāja-parameśvara*', and the facts that Mandasor was apparently the capital of Yaśodharman and that the engraver was an officer of Yaśodharman, go very strongly to suggest that Yaśodharman and very probably Viṣṇuvardhana were names of one and the same King.[1]

In the opening verse the poet pays homage to *Śiva* who is the lord of the Universe. The splendour of his teeth gleans forth when he smiles, or utters something or sings. It is that splendour which looks like the lusture of lightning sparkling in the night which envelops and brings into full view all the universe. Here, the poet seems to be reminded of the laughter of Lord Śiva described by Kālidāsa.[2] The use of the term '*jagatām patiḥ*' also deserves notice. The term means 'lord of the worlds'. The authors generally in such cases use the '*tatpuruṣa*' compound where the latter component is more significant. Here, the poet has avoided the compound only to emphasise the word '*jagatām*', which implies that Śiva was lord not of any one world only but of all the worlds. Similarly out of a number of synonyms of Śiva, the poet has chosen the word '*pinākin*' to convey the idea of the valour of Śiva. The employment of such appropriate and significant synonyms constitutes what Kuntaka has termed as *paryāyavakratā* (*i.e.* the charm arising out of appropriate synonyms).

According to the Paurāṇic mythology Brahmā, Viṣṇu and Maheśa were responsible for creation, preservation and destruction respectively.[3] But later on the devotees of a god attributed all these three powers to their own deity. Hence the powers of creation, preservation and destruction have been attributed to Lord Śiva in the second verse[4] of the Inscription. One is reminded of Kālidāsa's *Raghuvaṁśa* in the poet's description of Śiva as father of all the worlds in the second verse.[5]

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[1] *S.I.*, pp. 411–12 f.n. 1.

[2] *Rāśībhūtaḥ pratidinamiva tryambakasyāṭṭahāsaḥ. ||* *Meghadūta*, V.5.

[3] *Brahmatve sa prajāḥ sṛṣṭvā tataḥ sattvātirekavān |*
viṣṇutvametya dharmeṇa kurute paripālanam ||
tatastamoguṇodrikto Rudratve cākhilaṁ jagat |
upasaṃhṛtya vai śete trailokyaṁ triguṇo'guṇaḥ || *Mārk. Purāṇa.* 46.14.15.

[4] *Svayambhūrbhūtānāṁ sthitilayasamutpattividhiṣu*
prayukto yenājñāṁ vahati bhuvanānāṁ vidhṛtaye |
pitṛtvaṁ cānīto jagati garimāṇaṁ gamayatā
sa Śambhurbhūyāṁsi pratidiśatu bhadrāṇi bhavatām ||

[5] *jagataḥ pitarau vande Pārvatī–Parameśvarau.* *Raghu.* 1,1,

The well built by Dakṣa has been referred to in two verses only *viz.*, verses 4 and 25. In verse 4 the poet wishes that the ocean dug out by the sixty-thousand sons of Sagara may protect the glory of the well. Here by ocean, the poet means, by indication (*lakṣaṇā*) the deity of the ocean *i.e.* Varuṇa and requests him to protect the glory and fame of the well. Varuṇa, from the times of the *Ṛgveda* has been associated with the waters.[1] By the time of the *Purāṇas* Varuṇa lost the importance he had attained in the Vedic times. But his position as a presiding deity of the waters did not undergo any change even in the later mythology.

In the fifth verse the poet has paid homage to King Yaśodharman. He is a lord of the people. He possesses undaunted courage and prowess and therefore he pushes through the army of his enemies as easily and happily as he enters into a grove of thorn-apple trees. In doing so he sometimes gets wounded, but he does not seem to be worried about it and takes the wounds to be the young sprouts stuck to his body while he plucks, as it were, his fame by bending down the reputation of heroes like the tender creepers of trees. Here, the poet may be charged of indulging in the description of the wounds on Yaśodharman's body which produces a distasteful effect, but the beauty of the verse lies in the fact that he does not lose heart even after being badly wounded by the army of the opponents and that he still robs them of their glory.

Viṣṇuvardhana has brought into subjection the kings of east and north with peaceful overtures and by war.[2] Thus he acquired the second name of 'supreme king of kings' (*rājādhirāja*) and 'supreme lord' (*parameśvara*) for himself. Here the poet hints at the twin qualities of the King which has been attributed to King Dilīpa by Kālidāsa.[3] Besides, it also goes to show the diplomatic moves of Viṣṇuvardhana. He knew that he could subdue the people of different temperaments with different methods. The same has also been emphasised by the ancient authors on polity.[4]

The countries so conquered by Viṣṇuvardhana became happy and affluent. It is the fruits of Viṣṇuvardhana's noble and virtuous deeds that the subjects reaped in the form of happiness and affluence. The poet has depicted a picture of the peaceful, pious and pleasant atmosphere of the kingdom in the following verse—

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[1] *Vedā yo vīnāṁ padamantarikṣeṇa patatām |*
veda nāvaḥ samudriyaḥ || R.V. 1.25.7

[2] *Prāco nṛpān subṛhataśca bahūnudīcaḥ*
sāmnā yudhā ca vaśagān pravidhāya yena |
nāmāparaṁ jagati kāntamado durāpaṁ
rājādhirāja–Parameśvara ityudūḍham || Verse 7.

[3] *Bhīmakāntairnṛpaguṇaiḥ sa babhūvopajīvinām |*
Adhṛṣyaścābhigamyaśca yādoratnairivārṇavaḥ || *Raghu* 1.16.

[4] *Lubdhamarthena gṛhṇiyāt sādhum añjalikarmaṇā |*
mūrkhaṁ chandānurodhena tattvārthena ca paṇḍitam || Mallinātha on *Kirāta* 1.12.

Snigdhaśyāmāmbudābhaiḥ sthagitadinakṛto yajvanām ājyadhūmrai-
rambhomedhyaṁ maghonāvadhiṣu vidadhatā gāḍhasampannasasyāḥ |
saṁharṣād vāṇinīnāṁ kararabhasahṛtodyānacūtāṅkurāgrā
rājanvanto ramante bhujavijitabhuvā bhūrayo yena deśāḥ || v. 8.

"Through him, having conquered the earth with (his own) arm, many countries—in which the sun is obscured by the smoke, resembling dense, dark blue clouds of the oblation of the sacrifice, which abound with thick and thriving crops through (the god) Maghavan pouring cloudfuls of rain upon (their) boundaries, (and) in which the end of the fresh sprouts of the mango trees in parks are eagerly plucked in joy by the hands of wanton women, enjoy the happiness of being possessed of a good king !"

Here, by describing the happiness and affluence of the King the poet wants to convey the idea that it was all due to the virtuous King—and the poet has actually put it on record in the words *rājanvanto ramante*. During Viṣṇuvardhana's reign the subjects could easily perform sacrifices, being pleased with which Raghavan (Indra) granted rains which in turn made the earth fertile and green with vegetation. This verse again reminds us of Kālidāsa who says in the *Raghuvamśa*, that King Dilīpa and Maghavan used to look after their respective kingdoms with mutual help and co-operation.[1] There was complete law and order in Viṣṇuvardhana's kingdom and even the beautiful young ladies could loiter about alone in the mango groves and play there quite safely.

Viṣṇuvardhana belonged to a noble family. Not only his ancestors were virtuous, but even their servant Ṣaṣṭhidatta by name was a man of high ideals, who had conquered the six enemies *viz.*, desire, wrath, covetousness, bewilderment, pride and envy, which impede the practice of religion[2]. From Ṣaṣṭhidatta originated a race of merchants (*naigamas*). The piety of the race has been likened to that of the flow of the Ganges which comes out of the Himalayas and the water of the river Revā flowing from the moon. Here the Himalayas and the moon stand in comparison to Ṣaṣṭhidatta, who was as upright as the Himalayas and as pleasing to the world as the moon[3].

While describing the geneology of Ṣaṣṭhidatta, the poet has used apt similes which convey the characteristics of the persons so described. For example, Varāhadāsa seemed to be the Great Boar, the third incarnation of the god Hari (Viṣṇu) and suggested by the name Varāhadāsa itself. As the Great Boar picked up the earth and saved it from being drowned in the waters, so was Varāhadāsa, the protector of the earth. Varāhadāsa's son Ravikirti resembled the sun god (*ravi*) in as much as he illumined his family with his noble deeds in the same manner as the sun illumines the lofty summits of the fabulous mountain Udayagiri. Ravikīrti sustained the pure and undeviating path of traditional law which was acceptable to the good. On this account nobility of birth was not made a thing of false assertion with him. Ravikīrti gave birth to three sons through his wife Bhānudattā. They were Bhagavaddoṣa, Abhayadatta and Doṣakumbha. These three sons have been likened to three sacrifices performed with a fire in the form of Ravikīrti. The poet was well acquainted with the didactic teachings of Vidura, as mentioned in the *Mahābhārata*. It is evident from the fact that he has compared Bhagavaddoṣa's foresightedness with that of Vidura. He was well versed with statesmanship as well as with the science of meaning. The term '*gahvare'pyarthamārge*' may also mean deep polity and thus, Bhagavaddoṣa may also be taken as one who was fully conversant with the rules of polity. The phrase '*vacana-racana-bandhe Saṃskṛta-Prākṛte yaḥ kavibhiruditarāgam*' also means that he was sung by the poets in both Sanskrit and Prākṛt. It may, therefore, be inferred from this that besides the present inscriptions, the record of Bhagavaddoṣa's glorious deeds might have been preserved in other ways also.

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[1] *Dudoha gāṁ sa yajñāya sasāya Maghavā divam |*
sampadvinimayenobhau dadhaturbhuvanadvayam || Raghu 1.92

[2] *Tasya prabhorvaṁśakṛtāṁ nṛpāṇāṃ*
pādāśrayādviśrutapuṇyakīrtiḥ |
bhṛtyaḥ svanaibhṛtyajitāriṣaṭka
āsīdvasīyān kila Ṣaṣṭhidattaḥ || v. 10

[3] *Himavata iva Gāṅgastuṅganarmraḥ pravāhaḥ*
śaśabhṛta iva Revāvārirāśiḥ prathīyān |
paramabhigamanīyaḥ śuddhimānanvavāyo
yata uditagarimṇastāyate naigamānām || v. 11

Abhayadatta was of no less merits. He was possessed of a keen insight through which he used to detect the causes for the fear of his subjects and tried to remove them with all his might. This was the secret of his success which he attained day by day. Not even a trifle could escape Abhayadatta's eye even at night. This goes to show the vigil which he used to keep over his kingdom. Thus, Abhayadatta's way of undertaking his administration was not different from what we come to know about Duryodhana's as revealed by the spy in the *Kirātārjunīya* of Bhāravi.[1]

Dharmadoṣa, son of Doṣakumbha, was also a very dutiful ruler. He, by his just and pious rule, had changed, as it were, the *Kaliyuga* into *Satyayuga*. Although the *Smṛtis* recognise *anuloma* marriages, by the time of Dharmadoṣa, such marriages had become a taboo in the social structure of India and that is why he is eulogised as one in whose reign there was no possibility of the offsprings of mixed castes being born.[2]

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[1] *Kṛtāriṣaḍvargajayena mānavī-*
magamyarūpām padavīm prapitsunā |
vibhajya naktandivamastatandriṇā
vitanyate tena nayena pauruṣam || *Kirāta.* 1.9.

[2] *Vihitasakalavarṇāsaṅkaraṁ śāntaḍimbaṁ*
kṛta iva kṛtametadyena rājyaṁ nirādhi |
sa dhuramayamidānīm Doṣakumbhasya sūnu-
rguru vahati tadūḍhaṁ dharmato Dharmadoṣaḥ || *Ibid.* v. 20

The poet has put on record that the great well was constructed in the spring season. It is in this connection that the poet has given a picturesque, though conventional, description of this season (v. 25).

Yasminkāle kalamṛdugirāṁ kokilānāṁ pralāpā
bhindantīva smaraśaranibhāḥ proṣitānāṁ manāṁsi |
bhṛṅgālīnāṁ dhvaniranuvanaṁ bhāramandraśca yasmi-
nnādhūtajyaṁ dhanuriva nadacchrūyate puṣpaketoḥ ||

"In the season in which the songs of the cuckoos resembling the arrows of cupid, which are low and tender, cleave open, as it were , the minds of those who are far away from home ; and in which the humming of bees, sounding low on account of the burden (that they carry), is heard through the woods, like the resounding bow of (cupid) who has the banner of flowers, when its string is caused to twang.'

The above verse of the Inscription seems to be a reproduction of the following verse of Kālidāsa's *Ṛtusaṁhāra* (6.1)-

Praphullacūtāṅkuratīkṣṇasayāko
dvirephamālāvilasaddhanurguṇaḥ |
manāṃsi veddhuṁ surataprasaṅginām
vasantayodhā samupāgataḥ priye ||

" Oh dear ! the spring season has arrived like a warrior to cut through the hearts of the lovers desirous of cohabitation. The mango blossoms are his arrows and the humming of the bees is the twanging of the string of his bow."

The other verse describing the beauty of this season reads as follows —

Priyatamakupitānāṃ kampayanbaddharāgaṁ
kisalayamiva mughdaṁ mānasaṁ māninīnām |
upanayati nabhasvānmānabhaṅgāya yasmin
kusumasamayamāse............ || V. 26

Here, the poet has tried to convey the influence of the spring season which excites the ladies to infatuation and make them forget everything about their indifference to their lovers and to surrender themselves to them. The heart of the ladies is as tender as a young sprout and hence it is agitated by the winds of this season.

The figures of sound and meaning employed by the poet are *anuprāsa* and *upamā* and *utprekṣā*. The repetition of the group of letters '*sṛjatu*' and '*bhavasṛjo*'; '*bhaṅgam*' and '*bhujaṅgaḥ* '; '*ājau jitī vijayate jagatīm*'; '*rājanvanto*' and '*ramante*'; '*sutaḥ prasūto yaśasāṁ prasūtiḥ* '; '*dhutadhīdīdhitidhvāntān* ' and '*adhvarān* '; '*vacana* ' and '*racana*'; '*valinamiva vilambaṁ kambalaṁ bāhuleyaḥ* ' and so on produces a musical effect. More charm is added to these repetitions when we feel that they have come in spontaneously without any extra labour on the part of the poet.

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While describing the qualities of Dharmadoṣa the poet says that he did not want any pleasure of the kingdom for his own enjoyment. He was a ruler, no doubt, but the kingdom to him was a mere decoration and he did not derive any pleasure out of it as the dewlap of a bull adds to its external beauty, but the bull does not make any use of it. Here, the pleasure and pelf of the kingdom have been compared to the dewlap of the bull, and Dharmadoṣa to the bull itself. As the bull is a sign of strength and sturdiness, so was Dharmadoṣa the prowess personified.[1]

In another verse the untimely death of Abhayadatta has been compared to the untimely cutting of a green tree which is very shady and is likely to bear delicious fruits when it is fully grown up.[2] The poet has used this simile only to convey the idea that Death to a man is as strong as a huge elephant to a young and green tree. Besides, as the trees provide shadow and fruits to everybody without any distinction; so Abhayadatta used to provide shelter to any body who wanted it without any discrimintion of caste and creed.

The charm of the figure *atiśayokti* based on *utprekṣā* may be seen in the following verse—

yasyotketubhirunmadadvipakaravyāviddhalodhradrumai-
ruddhūtena vanādhvani dhvaninadad-vindhyādrirandhrairbalaiḥ |
bāleyacchavidhūsareṇa rajasā mandāṁśu saṁlakṣyate
paryāvr̥ttaśikhaṇḍicandraka iva dhyāmaṁ ravermaṇḍalam || V. 9.

"Through the dust, grey like the hide of an ass, stirred up by his armies, which have their banners lifted on high and which have the *lodhra* trees tossed about in all directions by the tusks of the infuriated elephants and which have the crevices of the Vindhya mountains made resonant with the noise of their journeying through the forests, the orb of the sun appears dark and dull-rayed, as if it were an eye in a peacock's tail reversed'.

Viṣṇuvardhana owned a large army. When it marched through the forests and mountains it struck the dust which went up and covered the orb of the sun. At that time the sun lost its brightness and looked like a reversed tail of a peacock. The upper side of the tail of peacock is marked with bright spots but its lower part is somewhat grey. So has become the sun covered with the dust raised by the marching army. It is the convention of Sanskrit poets to describe the dust raised by the marching army. Māgha has described the scene of the marching army in the following verse—

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1. *Svasukhamanabhivāñchandurgame'dhvanyasangāṁ*
dhuramatigurubhārāṁ yo'dadhadbhar̥turarthe |
vahati nr̥pativeṣaṁ kevalaṁ lakṣmamātraṁ
valinamiva vilambaṁ kombalaṁ bāhuleyaḥ || V. 21

2. *Sukhāśreyacchāyaṁ pariṇatihitasvāduphaladaṁ*
gajendreṇārugṇaṁ drumamiva kr̥tāntena balinā |
pitr̥vyaṁ proddiśya priyam–Abhayadattam pr̥thudhiyā
prathīyastenedaṁ kuśalamiha karmmoparacitam || V-23

athoccakairjaraṭhakapotakandharā-
tanūruhaprakaravipāṇḍuradyuti |
balaiścalaccaraṇavidhūtamuccarad-
ghanāvalīrudacarata kṣamārajaḥ || *Śiśupālavadha* 17.52

Śrīharṣa (*Naiṣadha* 1.8) has his own idea of the marching army which is seen in this verse—

yadasya yātrāsu baloddhataṁ rajaḥ
sphuratpratāpānaladhūmamañjima |
tadeva gatvā patitaṁ sudhāmbudhau
dadhāti paṅkībhavadaṅkatāṁ vidhau ||

Whereas Māgha's imagniation could reach the clouds and Śrīharṣa's went to the moon, the imagination of the poet of the present inscription has touched the sun and he has made it covered with the dust raised by Viṣṇuvardhana's army.

The metres used in the inscription are as follows :—

Mālinī (verses 3, 5, 11, 13, 17, 18, 20, 21, 22 and 26) ; *Sragdharā* (verses 8, 19 and 27) : *śloka* (verses 14, 15 and 16) ; *Upajāti*-with *Indravajrā* and *Upendravarjā*- (verses 4 and 12); *Sikhariṇī* (verses 2 and 23) ; *Vasantatilakā* (verses 6 and 7); *Śārdulāvikrīḍita* (verse 9) ; *Indravajrā* (verse 10) ; *Mandākrāntā* (verse 25); *Śālinī* (verse 28) ; *Āryā* (vrse 24) and *Puṣpitāgrā* (verse 1).

The metres used here are also significant. It may be shown by taking an illustration. Kṣemendra, in his *Suvṛttatilaka* has laid down that the metre *Śārdūlavikrīḍita* is most suited to the descriptions of the glory of the King etc.[1], and we find this metre used in the above verse of the Inscription *Yasyotketubhiḥ* etc. Here the poet is describing the glory of Viṣṇuvardhana and hence, the appropriateness of the metre *śārdūlavikrīḍita* needs not be reiterated. However, the *Śārdūlavikrīḍita* used here cannot be ranked high as in this metre the first half of the verse should contain uncompounded words while the second half should abound in compounds.[2] Here, both the first and the second halves of the verse abound in compounds, at least the second half does not have more compounded words than the first half.

2. *Mandasor Stone Pillar Inscription of Yaśodharman* :—

The Inscription is by the poet Vasula, the son of Kakka. It was inscribed by one Govinda.[3] The Inscription describes the glorious and chivalrous deeds of the King Yaśodharman, who ruled over the whole of northern India. It is non-sectarian and was meant to narrate the erection of the column for recording the glory and prowess of the King.

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[1] *Sauryastave nṛpādīnāṃ śārdūlakrīḍitaṁ matam ||* S.T. 3.22

[2] *Vicchinnapadaṁ pūrvārdhe dvitīyārdhe samāsavat |*
Śārdūlakrīḍitaṁ bhāti viparītamato'dhamam || S.T. 2.37

[3] *Iti tuṣṭūśayā tasya nṛpateḥ puṇyakarmaṇaḥ |*
Vāsulenoparacitāḥ ślokāḥ Kakkasya sūnunā || V. 9
Utkīrṇā Govindena.

The information which is gathered from the Inscription is that Yasodharman's kingdom stretched from the river Lauhitya or Brahmaputrā to the western ocean and from the Himalayas to the Mahendra.[1] There is a difference of opinion with regard to the identity of the Mahendra. Fleet[2] observes that 'it is doubtful whether this denotes here the famous Mahendragiri or Mahendrācala in the Ganjam District, among the Eastern Ghats; or another mountain of the same name, not so well known, which appears to be mentioned also in line 2 of an earlier Nasik inscription of the nineteenth year of Śrī-Pulumayi......and must be located somewhere in the Western Ghats'. Dr. Sircar, however, opines that Mahendra refers to the one in the Eastern Ghats and goes on to say that here, it means the Mahendrācala in the Tirunelveli District.[3] I am inclined to accept Dr. Sircar's views as the river Lauhitya and the Himalayas make the northern boundary and Mahendra and Western Ocean *i.e.*, the Arabian sea eastern and western boundaries respectively of Yaśodharman's territory. It is also evident that Yaśodharman was posterior to the Guptas and Hūṇas whom he is said to have exceeded so far as the territorial expanse is concerned.[4] The poet fancies that the earth was not conquered by Yaśodharman, rather it came of its own accord to seek shelter under the arm of the King, tormented as it was, by the kings who were haughty and arrogant and who lacked manners. This shows Yaśodharman's supremacy over his predecessors as well as his contemporaries whom he had defeated and whose territories he had annexed. It was this unique feat of chivalry that gave the title 'Emperor' (*samrāṭ*) for him. Yaśodharman was a staunch devotee of Lord Śiva. The statement that he never bowed his head before anyone else, human or divine except the god Sthāṇu (Śiva), goes to prove the matchless prowess of the King and his supremacy over all the human beings. As his territory was extended up to the mountain Himalayas, it (the Himalayas) has lost the pride of being accessible to human beings. That Mihirakula used to adore his feet shows that the former was a contemporary of the latter, who was no match to the former in any respect.[5]

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[1] *Ā Lauhityopakaṇṭhāttalavanagahanopatyakādā Mahendrā-*
dā Gaṅgāśliṣṭasānostuhinaśikhariṇaḥ paścimādāpayodheḥ |
sāmantairyasya bāhudraviṇahṛtamadaiḥ pādayorānamadbhi-
ścūḍāratnāṁśurājivyatikaraśabalā bhūmibhāgāḥ kriyante || V. 5

[2] *C.I.I.* p. 146, f.n. 1.

[3] *S.I.* p. 419, f.n. 3.

[4] *Ye bhuktā Guptanāthairna sakalavasudhākrāntidṛṣṭapratāpai-*
rnājñā Hūṇādhipānāṁ kṣitipatimukuṭāddhyāsinī yān praviṣṭā |
deśāṁstāndhanvaśailadrumagahanasaridvīrabāhūpagūḍhā-
nvīryāvaskannarājñaḥ svagṛhaparisarāvajñayā yo bhunakti || V. 4

[5] *Sthāṇoranyatra yena praṇatikṛpaṇatāṁ prāpitaṁ nottamāṅgaṁ*
yasyāśliṣṭo bhujābhyāṁ vahati himagirirdurggaśabdābhimānam |
nīcaistenāpi yasya praṇatibhujavalāvarjjanakliṣṭamūrdhnā
cūḍāpuṣpopahārair-Mihirakulanṛpeṇārccitaṁ pādayugmam || V. 6

The column was made to be erected by the King Yaśodharman himself, who, as has been referred to above, was a staunch devotee of Śiva. It is therefore appropriate that the Inscription should open with a benedictory verse paying homage to the lofty banner of Śiva, carrying he emblem of the bull which is marked with the signs of the five fingers of Pārvatī.[1] This mark has got some holy significance. Even to-day on certain auspicious occasions the ladies put these marks on the walls and other places. Besides, such marks are put to prove the ownership and hence, Pārvatī put them on the body of the bull to assert her ownership over it. The bull is so strong that it drives away the demons by its terrible bellowings and makes the glens of Sumeru to have their rocks split open by the blows of his horns. The lofty banner of Śiva is invoked for driving away the glories of the enemy. When the bull can drive away the evil spirits why cannot the banner, which is marked by it, do the same with regard to the glories of the adversaries of the devotees of Śiva.

King Yaśodharman has been described as affording protection to the earth which was persecuted by the wicked and hence he was ranked among the ancient kings and law-makers such as Manu, Bharata, Ālarka and Māndhatā. These persons have become immortal by their noble deeds and so has become Yaśodharman. Like the ancient kings and law-makers, Yaśodharman too is born in a noble family, is possessed of piety and handsomeness, is an abode of Duty ' and controlled by him, the conduct of mankind does not swerve (from the right course)'.[2]

Figures of meaning such as *upamā* and *utprekṣā* have been aptly used by the poet. Let us take the following verse—

nindyācāreṣu yo'sminvinayamuṣi yuge kalpanāmātravṛttyā
rājasvanyeṣu pāṁsuṣviva kusumabalirnābabhāse prayuktaḥ |
sa Śreyo-dhāmni samrāḍiti Manu-Bharata-Alarka-Māndhātṛkalpe
kalyāṇe hemni bhāsvanmaṇiriva sutarāṁ bhrājate yatra Śabdaḥ || V. 3.

'That word which, in this age which is the destroyer of good behaviour, applied only in an unreal manner to other kings who adopted a reprehensible course of conduct, and (therefore) does not shine just as an offering of flowers in the dust; but, in whom, possessed of a wealth of virtue, and so like Manu, Bharata, Alarka and Māndhātā, that name 'universal sovereign' (*samrāṭ*) shines forth, like a resplendent jewel set in auspicious gold.'

Here, the poet justifies the title '*Samrāṭ*' conferred on Yaśodharman. Had this title been conferred on any King other than Yaśodharman, it would have lost

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1. *Vepante yasya bhīmastanitabhayasamudbhrāntadaityā digantāḥ*
   śṛṅgāghātaiḥ sumerorvighaṭitadṛṣadaḥ kandarā yaḥ karoti |
   ukṣāṇaṁ taṁ dadhānaḥ kṣitidharatanayādattapañcāṅgulāṅkaṁ
   drāghiṣṭhaḥ Śūlapāṇeḥ kṣapayatu bhavatāṁ śatrutejāṁsi ketuḥ || V. 1
2. *Ślāghye janmāsya vaṁśe caritamaghaharaṁ dṛśyate kāntamasmin*
   dharmasyāyaṁ niketaścalati niyamitaṁ nāmunā lokavṛttaṁ | V. 8

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its beauty in the same manner as a flower loses its beauty by falling in the dust. By being conferred on Yaśodharman, on the other hand, the title itself has become more adorned like a gem set in auspicious gold. It is the gold which enhances the inherent lusture of the jewel. Similarly it is the personality of Yaśodharman which has added to the significance of the title. As the gold has got not only natural lusture, but it glitters more and more by being heated, so is Yaśodharman who has got intrinsic virtues in himself and seems to be more virtuous in adversities.

The figure *utprekṣā* may be illustrated in the following verse—

Gāmevonmātumūrdhvaṁ vigaṇayitumiva jyotiṣāṁ cakravālaṁ
nirdeṣṭuṁ mārgamuccairddiva iva sukṛtopārjjitāyāḥ svakīrteḥ |
tenā kalpāntakālāvadhiravanibhujā Śrī-Yaśodharmaṇāyaṁ
stambhaḥ stambhābhirāmasthirabhujaparigheṇocchritam nāyito'tra ||
Ślāghye janmāsya vaṁśe caritamaghaharaṁ dṛśyate kāntamasmin
dharmasyāyaṁ riketaścalati niyamitaṁ nāmunā lokavṛttam |
ityutkarṣaṁ guṇānāṁ likhitumiva Yaśodharmaṇaścandrabimbe
rāgādutkṣipta uccairbhuja iva rucimānyaḥ pṛthivyā vibhāti ||

Verses 7 & 8.

'By that glorious king, Yaśodharman, the firm beams of whose arms are as charming as pillars, this column, which shall endure to the time of the destruction of the world, has been erected here, as if to measure out the earth, as if to enumerate on high the multitude of the heavenly lights; and as if to point out the path of his own fame to the skies above, acquired by good actions; this column which shines refulgent, as if it were the lofty arm of the earth, raised up in joy to write upon the surface of the moon the excellence of the virtues of Yaśodharman, to the effect that " his birth is in a lineage that is worthy to be eulogised; there is seen in him a charming behaviour that is destructive of sin; he is the abode of duty; and the conduct of mankind kept in order by him, does not swerve.'

The girth and the height of the column have been described here by the poet with the aid of several imageries. To describe the thickness of the column the poet imagines that it wants to measure, as it were, this extensive earth. Describing the height of the column the poet fancies as if it wants to count the stars in the sky. It is our common experience that sometimes when there are so many things which one wants to count, one does so by pointing at and sometimes even by touching them one by one. The column has risen so high only to touch each one of the stars so as to count them very accurately; or the column may be a pointer to direct the fame of Yaśodharman to the region of the celestial beings, so that it may not go astray, hard-earned as it is by the King; or the huge column may be the arm of the earth raised up high to announce his glory; or else it may be the hand of the earth raised up high to inscribe on the surface of the moon the personal history and glory of Yaśodharman. Here, the poet seems to be influenced by the poet of the Allahabad Pillar Inscription of Samudragupta, wherein the height of the pillar has been

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described thus—'*Mahārājādhirāja-Śrī-Samudraguptasya.....Kīrtimitastridaśapatibhavanagamanāvāptalalitasukhavicaraṇāmācakṣāṇa iva bhuvo bāhurayamucchritaḥ stambhaḥ.*'

The inscription has been composed in two metres—*sragdharā* and *śloka.* Verses 1 to 8 are composed in the *sragdharā* metre and the last verse is in the *śloka.* Kṣemendra, the celebrated author of the *Suvṛttatilaka* has observed that the metre *sragdharā* is most suited to the descriptions of the hard-blowing winds etc.[1] Here, however, the poet has made apt use of this metre in describing the prowess of King Yaśodharman. The brave and chivalrous King has swept over his enemies like a hurricane which sweeps over everything coming on its way. He could not be stopped without achieving his aim as the path of the wind cannot be obstructed by anything, not even by the high mountains.

The *guṇa ojas* is prevalent throughout. It aids in the delineation of the sentiment of heroic — the predominant sentiment of the inscription which is an account of the brave and chivalrous deeds of King Yaśodharman couched in lucid poetry.

Thus, viewing these inscriptions of Central India from all aspects it may be reiterated that Sanskrit has played an important role in enriching the treasure of Epigraphy, which in its turn has contributed liberally to Sanskrit literature. The inscriptions which have been dealt with in this limited space will prove that the theme, diction, figures of sound and meaning and the metres are the same which have been handled by the great Sanskrit poets like Kālidāsa, Bhāravi, Māgha and Śrīharṣa.

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[1] *Sāvegapavanādīnāṁ varṇane sragdharā matā* / S.T. 3.22

EPIGRAPHIC SANSKRIT IN GUJARAT IN THE ANCIENT PERIOD

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It was as early as in 1913 that the English translation of Dr. Buhler's booklet, "*The Indian Inscriptions and the Antiquity of Indian Artificial Poetry*', published in Vol. XLII of *Indian Antiquary*, drew the attention of Sanskrit scholars to the literary merit of certain inscriptions of ancient India. Therein Dr. Buhler commented on the literary merit of Vatsabhaṭṭi's *praśasti* on the Sun-temple at Daśapura (Mandasor) and Hariṣeṇa's panegyric of Samudragupta. From the literary study of these inscriptions he showed that the Kāvya literature was in bloom during the Gupta period, in the beginning with the fourth century. For earlier times he turned to the Junagadh Rock Inscription of Rudradāman, which he more properly designated "The praśasti of the restoration of the Sudarśana lake, during the reign of Mahākshatrapa Rudradāman." He introduced this record as "the only great Sanskrit Inscription, which can be, with certainty, placed in a considerably earlier age' (p. 188). It was written just after the restoration of the reservoir which shortly followed its destruction in 150-151 A. D. From the literary study of this inscription Dr. Buhler proved most conclusively" that "even during the second half of the second century, there was in existence a *Kāvya* literature (p. 190). As he remarks, "it contains a *gadya Kāvya* as such." Its style is similar to that of the prose part of Hariṣeṇa's *Kāvya* in many respects and besides the use of *alaṁkāras*, there is an obvious effort on the part of the poet, to satisfy all the requirements prescribed for prose composition in poetics. The author knew very well that *ojas* or *samāsabhūyastva*, the frequency and length of compounds, is the principal feature of a prose composition. In the *praśasti* compounds occur more frequently than single words and the compounds often exhibit a conspicuous length. The *praśasti*[1] contains only five sentences measuring 49 units, of which the fourth sentence alone consists of more than 23 units. Compounds consisting of about ten words and extending over twenty letters are numerous. For example,

[मृत्ति]कोपलविस्तारायामोच्छयनिःसन्धिबद्धदृढसर्वपाळीकत्वात् (l. 1), गिरिशिखरतरुतटाट्टालकोपतल्पद्वारशरणोच्छयविध्वंसिना (l. 6), पूर्वापराकरावन्त्यनूपनीवृदानर्तसुराष्ट्रश्वभ्रमरुकच्छसिन्धुसौवीरकुकुरापरान्तनिषादादीनां (l. 11), स्फुटलघुमधुरचित्रकान्तशब्दसमयोदारालंकृतगद्यपद्य[काव्यविधानप्रवीणे]न (l- 14).

The epigraph abounds in Śabdālaṁkāras, for instance : पर्वतपादप्रतिस्पर्द्धि (ll. 1-2), गुरुभिरभ्यस्तनाम्नो रुद्रदाम्नो (l. 4), सृष्टवृष्टिना (l. 5), निस्सृतसर्वतोयं

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[1] Junagadh Rock Inscription of Rudradāman I (*E.I.*, Vol. VIII, pp. 42 ff.)

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(l. 8), प्रहरणवितरण° (l. 10), नगरनिगमजनपदानां (ll. 10-11), प्राप्तधर्मार्थकाम-विषयाणां विषयाणां (l. 11), °विधेयानां यौधेयानां (l. 12), हस्तोच्छ्रयार्जितधर्मानुरागेन (l. 13), °न्यायाद्यानां विद्यानां (l. 13), पारणधारण° (l. 13), दानपानावपान° (l. 13), प्रमाणमानोन्मानं (l, 14), °नाम्ना °दाम्ना महाक्षत्रपेण रुद्रदाम्ना (l. 15), and आर्येणाहार्य्येण (l. 19).

As for Arthālaṁkāras, we notice Upamā in पर्वतपादप्रतिस्पर्द्धि (ll. 1-2), युगनिधनसदृशपरमघोरवेगेन वायुना (l. 7), and मरुधन्वकल्पम् (l. 8); Utprekṣā in एकार्णवभूतायां पृथिव्यां (l. 5); and Śleṣa in [इदं तडाकं सुदर्शनं]...... दुर्द[र्शनमासीत् ।] (l. 8).

The poet presents the contents of his narrative in detail, and lays less emphasis on the use of poetic imagery and Arthālaṁkāras. However, the expression for Rudradāman's skill in poesy, is very significant, as it contains the views of the author regarding the requirements of a good composition (p. 192).

Romances in high prose are known to have been composed in the 6th and 7th centuries, as for instance, *Daśakumāracarita* by Daṇḍin, *Vāsavadattā* by Subandhu and *Harṣacarita* and *Kādambarī* by Bāṇa. But the *praśasti* engraved in this inscription of the time of Mahākshatrapa Rudradāman makes it clear that such a high prose style in Sanskrit already existed in the second century, a specimen being available in an inscription in Gujarat.

As Dr. Buhler has remarked, the language of this record shows several deviations from the usage of classical poets and even presents some actual mistakes.[2] Further it also shows some influence of Prākṛt[3]. It also contains the use of ळ for ल in certain words, as in सर्वपाळीकत्वात् (l. 1), प्रनाळी (l. 0), and व्याळ (l. 21).

This style continued in Gujarat in the eulogistic passages pertaining to the royal donor and his predecessors, given in the copper-plate grants issued by the Maitraka Kings of Valabhī.[4] They are dated years 206 to 447 of the Valabhī Era, i.e., 525 A. D. to 766 A. D. The frequency of long compounds and common use of Śabdālaṁkāras are noticed in almost all eulogistic passages, as for example in the eulogy of the Senāpati Bhaṭṭārka, the founder of the dynasty : प्रसभप्रणतामित्राणां मैत्रकाणामतुलबलसपत्नमण्डलाभोगसंसक्तप्रहारशतलब्धप्रतापः प्रतापोपनतदानमानार्ज्जवोपार्ज्जितानुरागानुरक्तमौलभृतमित्रश्रेणीबलावाप्तराज्यश्रीः ।

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[2] पर्जन्येन एकार्णवभूतायामिव पृथिव्यां (l. 5), वीशदुत्तराण्यायतेन (l. 7), तस्मिं भेदे (l. 9), अन्यत्र संग्रामेषु (l. 10), नीर्व्याजमवजीत्यावजीत्य (l. 12), धर्मानुरागेन (l. 13), प्रत्याख्यातारंभं (l. 17) and आनर्त सुराष्ट्रानां (l. 18),

[3] वीशदुत्तराण्यायतेन (l. 7), नीर्व्याजमवजीतयवजीत्य (l. 12).

[4] G. V. Acharya, *Historical Inscriptions of Gujarat, Part I*, Nos, 17–96,

Here the last two compounds consist of 10 and 16 words and extend to over 26 and 36 letters respectively. The *praśasti* also abounds in Yamaka and Anuprāsa. The *praśastis* also contain Arthālaṁkāras like Upamā, Rūpaka, Utprekṣā, Virodha, Vyatireka and Śleṣa. For example, **कल्पतरुरिव सुहृत्प्रणयिनां यथाभिलषितफलोपभोगदः, सुविशुद्धस्वचरितोदकक्षालितकलिकलङ्कः, रूपकान्तिस्थैर्य्यगाम्भीर्य्यबुद्धिसम्पद्भिः स्मरशशाङ्काद्रिराजोदधित्रिदशगुरुधनेशानतिशयानः, पादचारीव सकलभुवनमण्डलाभोगप्रमोदः, अधिगतकलाकलापः कान्तिमान्निर्वृतिहेतुरकलङ्कः कुमुदनाथः, कन्याया इव मृदुकरग्रहणादमन्दीकृतानन्दविधिर्व्वसुन्धरायाः, पयोदश्यामशिखरचूचुकरुचिरसत्वविन्ध्यस्तनयुगायाः क्षितेः** etc. Some eulogistic expressions contain good specimens of poetic imagery, as for example, **प्रणतप्रभूतपार्थिवकिरीटमाणिक्यमसृणितचरणनखमयूखरञ्जिताशेषदिग्वधूमुखः, पूर्वमेव विविधवर्णोज्ज्वलेन श्रुतातिशयेनोद्भासितश्रवणः, पुनः पुनरुक्तेनेव रत्नालङ्कारेणालङ्कृतश्रोत्रः, परमहीपतिस्पर्शनाशनधियेव लक्ष्म्या स्वयमतिस्पष्टचेष्टमाश्लिष्टाङ्गयष्टिः** etc. These expressions also abound in Anuprāsa. Certain expressions remind us of similar expressions in the works of Kālidāsa. For instance, **प्रजाहृदयरञ्जनादन्वर्थराजशब्दः** in the eulogy of Guhasena would remind us of **तथैव सोऽभूदन्वर्थो राजा प्रकृतिरञ्जनात् ॥** (*Raghuvaṁśa* IV, 11) ; and **दर्शयिता श्रीसरस्वत्योरेकाधिवासस्य** in the eulogy of Dharasena II bears resemblance to **एकसंश्रयदुर्लभं सङ्गतं श्रीसरस्वत्योः** in *Vikramorvaśīya* and **एकसंस्थं यस्मिन्द्वयं श्रीश्च सरस्वती च,** *Raghuvaṁśa* (III-29).

Predilection for the use of Śabdālaṁkāras is also reflected in usual documentary expressions as well, as for example, **सर्वानेव समाज्ञापयति, अस्तु वस्संविदितं, मातापित्रोः पुण्याप्यायनाय, सोपपातकैः संयुक्तः स्यात्, भगवता वेदव्यासेन व्यासेन** etc.

The copper edicts of other dynasties of the Maitraka period (circa 470-788 A.D.)[5], too, contain similar expressions in their eulogistic passages, for example, **भगवत्पादकर्मकरः करगतक्रमागतं, शारदरजनिकररुचिरवपुः** and **सुचरितनिदर्शनार्थमिव निर्म्मितः** in the Traikūṭaka grants ; **विविधविमलगुणरत्नसंपदुद्भासितसकलदिङ्मुखे परित्राताशेषसपक्षमहीभृति सततमविलङ्घितावधौ स्थैर्य्यगाम्भीर्यलावण्यवति महासत्त्वतयातिदुरवगाहे गुर्जरनृपतिवंशमहोदधौ, धर्मस्येव क्रतुः, सर्वप्रदानशीलोऽपि परयुवतिहृदयदानपराङ्मुखः, अनेकसमरसङ्कटप्रमुखागतनिहतशत्रुँसामन्तकुलवधूप्रभातसमयरुदितच्छलोद्गीयमानविमलनिस्त्रिंशप्रतापः, निशितनिस्त्रिंशधारादारितारातिकरिकुम्भमुक्ताफलच्छलोल्लसितयशोंऽशुकगुण्ठितदिग्वधूवदनसरसिजः** in the Gurjara edicts, **शरदमलसकलशशधरमरीचिमालावितानविशुद्धकीर्त्तिपताकाविभासितसमस्तदिगन्तरालः, अनेकैरपि नरेन्द्रवृन्दवृन्दारकैरजितपूर्वैः............स्वशिरःप्रदानेनाद्य तावदेकजन्मीयमित्येव मिषोपजातपरितोषा-**

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[5] V. V. Mirashi, *Corpus Inscriptionum Indicarum*, Vol. IV, Nos. 8–30.

नन्तरप्रहतपटुपटहरवप्रवृत्तकबन्धबद्धरासमण्डलीके समरशिरसि in the edicts of the Chālukya Kings of Navasari.

The style of the Maitraka edicts was further continued by the Saindhava Kings who ruled over Western Saurashtra even after the fall of Valabhi[6]. Their edicts are dated 832 to 915 A.D. The eulogy of Kings is here made in a similar high prose style. For example श्यामलितसगर्वशत्रुसामन्तसीमन्तिनीवदनारविन्दद्युतिः, प्रलयकालविजृम्भितज्वलनज्वालावलीकल्पानल्पप्रसरत्प्रतापः, करवाल इवापवर्जितसहजकलङ्कशङ्कः and विपुलविप्रतीकपयोधिबलजलनिमग्नस्वमण्डलोद्धरणसौकर्यलीलाप्रकटितमहावराहमहिमा.

Thus the copper edicts of the Maitraka period and the post-Maitraka period contain eulogistic passages composed in the high prose style characterised by long compounds, frequent use of Śabdālaṁkāras, and some expressions of poetic imagery.

The high prose style continued in the epigraphic records of Gujarat from the second century to the first quarter of the tenth century. It is conspicuously absent in those of the Chaulukya Kings (942-1304 A. D.) and their successors.

The epigraphic records of the Chaulukya period, however, contain some *praśastis* entirely composed in verse. *Praśastis* in verse had a long background in earlier times. The earliest epigraph in verse in Gujarat is the Devani-Mori stone Casket Inscription of the time of Rudrasena (III), dated Kathika year 127 (probably *circa* 375 A. D.).[7] But it simply presents bare facts in verse and has little literary value.

The earliest epigraph composed in verse in poetic style is the Junagadh Rock Inscription of the time of Skandagupta, dated 455-457 A. D.[8], Part I of the epigraph, entitled' **'सुदर्शन-तटाक-संस्कार-ग्रन्थ-रचना'**, is composed in 39 stanzas in various metres like Mālinī, Āryā, Upajāti, Indravajrā, Vaṁśastha and Vasantatilakā. It is a poetic composition embodying high imagery in some verses, for instance

इमाश्च या रैवतकाद्विनिर्गताः पलाशिनीयं सिकता विलासिनी ।
समुद्रकान्ताः चिरबन्धनोषिताः पुनः पतिं शास्त्रयथोचितं ययुः ॥ २८ ॥
अवेक्ष्य वर्षागमजं महोद्भ्रमं महोदधेरूर्जयता प्रियेप्सुना ।
अनेकतीरान्तजपुष्पशोभितो नदीमयो हस्त इव प्रसारितः ॥ २९ ॥

The verses run in the smooth Vaidarbhī style of the Gupta age. Yet it sometimes incorporates also the smooth use of Śabdālaṁkāras, as in स जयति विजितार्त्तिर्विष्णुरत्यन्तजिष्णुः (Śl. 1). A large portion of Part II pertaining to the erection of the temple of Cakrabhṛt is lost, yet the extant portions testify the same style of poetic composition.

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[6] *Epigraphia Indica*, Vol. XXVI, pp. 185 ff.

[7] R. N. Mehta and S. N. Chowdhary, *Excavation at Devni Mori*, p. 121

[8] J.F. Fleet, *Corpus Inscriptionum Indicarum*, Vol. III, pp. 58 ff

Unlike the copper edicts of the Maitraka and other dynasties, those of the Rāshtrakūṭa kings who ruled over the Gujarat mainland during the post-Maitraka period give the eulogy of Kings in verse.[9] The verses are composed in various metres like Vasantatilakā, Gīti, Śārdūlavikriḍitā, Āryā, Sragdharā, Upajāti, Vaṁśastha, Anuṣṭubh, Pṛthvī, Śālinī and Mālinī. From the literary point of view, some of these verses are good pieces of composition, depicting the character and achievements of Kings in terms of poetic imagery and various figures of speech. For example,

चन्द्रो जडो हिमगिरिः सहिमः प्रकृत्या वातश्चलश्च तपनस्तपनस्वभावः ।
क्षारः पयोधिरिति तैः सममस्य नास्ति येनोपमा निरुपमस्तत एव गीतः ॥
यस्य विभोः कारायां रिपुरमणीचारुचरणलग्नानाम् ।
परुषरवो निगडानामनवरतं श्रूयते लोके ॥

The royal edicts for grants of land were usually composed by high officers like the Head of the Department of Peace and War and the Head of the Department of the Army.

The *Praśastis* of the Chaulukya period are, however, composed by accomplished poets and scholars. The earliest known *Praśasti* in verse bearing the name of its author is in the Mangrol Sodhli step-well Inscription of V.S. 1207 (1146 A.D.)[10]. It was composed by Paramapāśupatācārya Prasarvajña. It commences with

मुकुटः स हरस्य पातु वः शशिपङ्केरुहकन्दकाङ्क्षया ।
गगनादचिरेण यत्र सा सुरहंसीव पपात जाह्नवी ॥

The Vadnagar *Praśasti* composed by the blind poet (Śrīpāla, a favourite of King Siddharāja, in V. S. 1208 (1152) A. D.)[11], is one of the best *Praśastis* from the literary point of view. It gives a graphic description of Nagara or Ānandapura (Vadnagar), which was fortified by King Kumārapāla. The following verses illustrate the imagery and diction of the poet :

आब्रह्मादिऋषिप्रवर्तितमहायज्ञक्रमोत्तम्भितै-
र्यूपैर्दत्तकरावलम्बनतया पादन्यपेक्षाच्युतः ।
धर्मोऽत्रैव चतुर्युगेऽपि कलिनानन्दः परिस्पन्दते
तेनानन्दपुरेति यस्य विबुधैर्नामान्तरं निर्मितम् ॥ २० ॥
आश्रातद्विजवर्गवेदतुमुलैर्बाधिर्यमारोपितः
शश्वद्धोमहुताशधूमपटलैरांध्यव्यक्षं लम्भितः ।

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[9] G. V. Acharya, *Historical Inscriptions of Gujarat*, Part II, Nos. 120 to 136.

[10] *Historical Inscriptions of Gujarat*, Part II, No. 145.

[11] *Ibid*, No. 147.

नानादेवनिकेतनध्वजशिखाघातैश्च खञ्जीकृतो
यस्मिन्नद्य वलिः स्वकालविहितोत्साहोऽपि नोत्सर्पति ॥ २१ ॥

The next outstanding *Praśasti* is given in the Prabhas Patan Stone Inscription of the Valabhī year 850 (1169 A.D.)[12]. The poet introduces himself as a *śīghrakavi*, but unfortunately his name is lost. It is a *Praśasti* of Bhāva Bṛhaspati, the pontiff who inspired King Kumārapāla to restore the celebrated temple of Somanātha. One verse would suffice to illustrate the style of the poet :

यद्रूपेक्षणवाञ्छया शतमखो धत्ते सहस्रं दृशां
यन्निस्सीमगुणस्तुतौ कृतधियो धातुश्चतुर्वक्त्रता ।
यन्माहात्म्यभराच्चलेति वसुधा गोत्राचलैः कीलिता
यत्कीर्तिर्न भुवि प्रयास्यति ततो नूनं त्रिलोकी कृता ॥ २१ ॥

The *Praśasti* by Pravarakīrti, dated V.S. 125 (X)[13], is but partly preserved. The Abu *Praśasti* of Kedārarāśi, composed by Lakṣmīdhara in V.S. 1265 (1208 A.D.)[14] has little poetic merit. But the Prabhas Patan *Praśasti* about the architectural contributions of Śrīdhara[15] is one of the best poetic compositions. It was composed in 60 verses in various metres in V.S. 1273 (1207 A.D.). Unfortunately almost all the lines are preserved incompletely and even the name of the poet is lost.

The *Praśasti* pertaining to the erection of Neminātha temple on Mt. Abu by Minister Tejaḥpāla in V.S. 1287 (1231 A.D.) is composed by Someśvaradeva, the hereditary Purohita of the Chaulukya kings of Gujarat and the author of *Kīrtikaumudī*, *Surathotsava*, *Ullāgharāghava*, *Rāmaśataka* and other works. It consists of 74 verses composed in various metres. It commences with an invocation of Sarasvatī and Neminātha and glorifies the lineage of Minister Tejaḥpāla (3-24), the Chaulukya King Vīradhavala whom he served (25-29), the local Paramāra King Somasimhadeva of Abu (30-42), Minister Vastupāla and Tejaḥpāla (43-49), Anupamādevī, wife of Tejaḥpāla (50-68), and Vijayasenasūri (69-71). Two verses may be cited here as examples of the poet's imagery :

तेन भ्रातृयुगेन या प्रतिपुरग्रामाध्वशैलस्थलं
वापीकूपनिपानकाननसरः प्रासादसत्रादिका ।
धर्मस्थानपरंपरा नवतरा चक्रेऽथ जीर्णोद्धृता
सत्संख्यापि न बुध्यते यदि परं तद्वेदिनी मेदिनी ॥ ६६ ॥

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[12] *Ibid*, No. 155.

[13] *Ibid*, No. 158–A.

[14] *Ibid*, No. 161.

[15] *Ibid*, No. 163.

Funding by IKS-MoE

शम्भोः श्वासगतागतानि गणयेद्यः सन्मतिर्योऽथ वा
नेत्रोन्मीलनमीलनानि कलयेन्मार्कण्डनाम्नो मुनेः ।
संख्यातुं सचिवद्वयीविरचितामेतामपेतापर-
व्यापारः सुकृतानुकीर्त्तनततिं सोऽप्युज्जिहीते यदि ॥ ६७ ॥

The Girnar Inscription dated V.S. 1288 (1232 A.D.) contain some verses composed for the eulogy of Vastupāla by Someśvaradeva, Naracandrasūri and Narendrasūri. The Vaidyanātha *Praśasti* at Dabhoi, dated V.S. 1311 (1255 A.D.)[16] is another poetic composition by Someśvaradeva, but it is fragmentary to a large extent.

Like Śrīdhara, Nānāka is a learned Brāhmaṇa, who has the honour to be the hero of *Praśasti*. One *Praśasti* (undated) of Nānāka is composed by the poet Kṛṣṇa, renowned as Bāla-Sarasvatī, and son of Ratna, author of *Kuwalayāśvacarita,*[17] and the other *Pruśasti*, dated V.S. 1328 (1271-72 A.D.), by poet Gaṇapati Vyāsa, the author of a *mahāprabandha* on *Dhārādhvaṁsa* by King Visāladeva.[18] Both the poets have eulogised the various merits of the Nāgara Poet, who was conversant with several branches of learning (such as Śruti, Smṛti, Nyāya, Kātantra, Metrics, Drama, Alanikāra, *Rāmāyaṇa, Mahābhārata,* Purāṇa) and who had established a *Sārasvata-krīḍāniketana* or *Sārasvatasadana* or *Sārasvatasaras.*

The Devapattana *Praśasti,* now preserved at Cintra in Portugal, is dated V.S. 1332 (1275 A.D.)[19]. It is a long *Praśasti* composed in 76 verses by poet Dharaṇīdhara. It eulogises the establishment of religious sanctuaries and endowments by Tripurāntaka, a pontiff of the Somanātha temple. It depicts the virtues of the pontiff in a lucid ornate style and also gives a succinct account of the early history of the Pāśupata sect and the pontiff's connection with the Gārgya branch of the sect.

Thus the ancient epigraphs of Gujarat contain some good *Praśastis* in prose and some in verse, which deserve appreciation as Sanskrit compositions with literary merit.

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[16] *Ibid.* No. 215.

[17] *Ibid.* No. 218.

[18] *Ibid.* No. 219.

[19] *Ibid.* No. 222.

काश्मीरे संस्कृतशिलालेखाः

SANSKRIT INSCRIPTIONS IN KASHMIR

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विदाङ्कुर्वन्त्वत्रभवन्तः, यत् काश्मीरमण्डले सांस्कृतिकी स्थितिश्चिराद् दृढमूलाभूत्। अत्रत्या भाषा काश्मीरी तु प्रायः संस्कृतस्यैव रूपान्तरमाश्रिता प्राकृतापरपर्याया प्रथिताऽस्ति । नास्ति तिरोहितमेतद्विदुषां यत् काश्मीरे राज्यभाषा मुस्लिम्शासनादर्वागपि संस्कृतमेव बभूव । मुस्लिम्शासनेऽपि प्रायः सार्धशतद्वयावधि संस्कृतेनैव राजकीयो व्यवहारः प्रचलति स्म । हिन्दुशासकानां काले संस्कृतं भाषासु सर्वोपरि वर्तते स्म । समस्तोऽपि सर्वकारीयः कार्यकलापः देववाणीमेवाधारीकृत्य प्रावर्तत । न केवलं पाठ्यक्रमः प्रत्नप्रणालीमाश्रित्य विद्यामठेष्वेव दृष्टिपथमवतरति स्म प्रत्युत आबालगोपं योषितोऽपि स्वजन्मभाषावदेव संस्कृतेन प्राकृतेन वा व्यवहरन्ति स्म, यस्योल्लेखो द्वादशशतकीयेन बिल्हणपण्डितेन विक्रमाङ्कदेवचरिताभिधानायाः स्वस्याः कृतेश्चरमे सर्गेऽकारि ।

अत्रानेके काश्मीरसभ्यतासंस्कृतिपोषका देवालयमठप्रासादविद्यालयप्रभृतयो विशिष्टाः स्मारका आसन् येषां निःशेषं क्रूरैर्यवनशासकैर्ध्वंसः कृतः, अवशेषाश्च यत्र तत्र स्थिता अद्यापि भारतीयान् पाश्चात्यानपि विदुषो विस्मयाम्बुधौ मज्जयन्ति । तत्रभवता कल्हणेनापि

विद्यावेश्मानि तुङ्गानि कुङ्कुमं सहिमं पयः ।
द्राक्षेति यत्र सामान्यमस्ति त्रिदिवदुर्लभम् ॥

इत्यनेन श्लोकेन विद्यावेश्मनां तुङ्गताप्रतिपादनेन त्रिदिवदुर्लभता वर्णितास्ति, अत्रत्या कतिपयनरेशाः ललितादित्य-प्रतापादित्य-अवन्तिवर्माणः स्वौजसा प्रतापेन च समस्तानपि स्वप्रातिवेशिकान् भारतीयान् नरेशानतिशेरते स्म । यद्यपि प्रोक्तनरेशानां बिरुदावलिशंसीनि चिह्नानि तथा तत्तदाश्रयलब्धप्रतिष्ठानि स्मारकाणि च सामस्त्येन नोपलभ्यन्ते तथा तदीयचरित्राण्यपि नामावशेषतामेव गतानि, तथापि यत्र तत्र तैः प्रतिष्ठापितानां देवालयवापीतडागादीनां शिलालेखाः मार्तण्ड(वर्तमान-महन)-प्रतापपुर(वर्तमान-नापर)-लोलाब-प्रदेशेष्वद्यापि दृश्यन्ते । तेषु मार्तण्डे शिलालेखाः ललितादित्यस्य (६५५-७३६ई०), तथा तज्जीर्णोद्धारकर्तुः रामदेवस्य च प्रतापपुरे प्रतापादित्यस्य वाङ्गतारण्ये जयसिंहदेवस्य (११२७-११४५ई०) सप्रमाणं स्थिरीक्रियन्ते । एतदतिरिक्तमनेकेषां एतद्देशीयानां नरेशानां सुवाच्यैरक्षरैरङ्किताः मुद्रा अपि प्रायेणोपलभ्यन्ते, येषु तोरमाण-हुष्क-कनिष्क-दुर्लभवर्धन-ललितादित्य-प्रतापादित्य-अवन्तिवर्म-दिद्दा-प्रभृतीनां नरेशानां मुद्रास्तु सुवाच्यैः

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शारदाक्षरैरङ्किताः काश्मीरप्रतापसङ्ग्रहालये सुरक्षिताः सन्ति । यासु काश्चन सौवर्ण्योऽपि लभ्यन्ते । काश्मीरे तु आदिमाः प्रायशः समग्रा अपि शिलालेखाः संस्कृत एव शारदालिप्यां समुट्टङ्किताः सन्ति । अत्र त्रयोदशी-शताब्द्यां तावत् हिन्दुशासकानां शासनं समुल्लसति स्म, उद्यानदेवस्य सहदेवस्य च समये काश्मीरेषु राज्यविप्लवः समजनि । परस्तात् कोटादेव्या विधर्मे दीक्षितत्वेन यवनधर्मदीक्षितेन बौद्धराजकुमारेण (रेंचनशाह) सुल्तान-सदर-उद्दीनाभिधेन, तन्मरणानन्तरं सुल्तान-शम्सउद्दीनेन सार्धं परिणयनेन सममेव काश्मीरः ४५७-वर्षपर्यन्तं विधर्मिशासकानां हस्तायत्तोऽभवत्, येन समये समये तदीयप्राबल्यात्तथा तत्कृतात्याचारातिरेकाच्च काश्मीरिकी संस्कृतिः प्रायेण ध्वस्ताभूत् । तदीयशासनस्य सार्धशतद्वयादूर्ध्वं राज्यभाषापदमधितिष्ठतः संस्कृतस्य स्थानं शनैः शनैः पारस्यभाषया गृहीतम् । किं च यवनराज्यकालेऽपि संस्कृतमिश्रेण पारस्यभाषामयेन कार्यकल्पेन राजकीयो व्यवहारः प्रचलति स्म यस्योद्धरणानि श्रीक्षेमेन्द्रकृते लोकप्रकाशकोषे उपलभ्यन्ते तावत् यथा-“संवत्सरेऽत्र दिने श्री प्रेनापितकदले रैज्जि-अमुकेन रैज्जि-अमुकपुत्रेण हस्ते सति बंगलचीरिका दत्ता । यथा अत्र आगरान्तरे खुज्या-अमुकः खुज्या-अमुकं प्रति लिखति-खुज्या-अमुके सलामबन्दगी ददनीयम्” इति ।

तथा समये समये यवनकर्तृकैरत्याचारैः काश्मीरिकमुख्यशिल्पनिदर्शकानि चिह्नानि बलाद् ध्वस्तानि संभाव्यते येषु नूनं शिलालेखा अपि स्युः । राज्यश्री-कालेश्वरी(कालश्री)-सद्भावश्री-महाश्री-प्रभृतीनां प्रत्नानां विशालदेवालयानां तोरणेष्वपि प्रतिष्ठासमये उत्कीर्णाः शिलालेखा अपि आक्रामकैर्यवनाधिकारिभिः नूनं विलुप्ता भवेयुः । एवमेव त्रिजयेश्वर-त्रिपुरेश्वर-कपटेश्वर-प्रवरेश्वरादीनां प्रसिद्धानामपि देवगृहाणां विध्वंसेन सार्धमेव ताश्शिलालेखाः समयदुःस्थित्या तैर्विनाशिता एव । किं बहुना, बहूनां प्रासादानां राजवेश्मनामाधाराः प्रवरपुर-ललितपुर-पद्मपुर-सिंहपुर(वर्तमानल्यतपोर-पम्पोर-स्यम्पोर)-प्रभृतिषु धामस्वपि नोपलभ्यन्ते । का कथा तदाधारस्थितानां शिलालेखानाम् ।

कदाचिद् हिन्दुशासकानां शिलालेखाः बौद्धैः, सौगतानं च हिन्दुशासकैः तत्तद्देवालयेन तत्तद्विहारेण च सार्धमेव विध्वंसं नीता इति आरीग्रामाभ्यन्तरे एकेन श्रीप्रतापसंग्रहालयस्थेन शिलालेखेन ज्ञायते ।

किं च मार्तण्डमहाभूमावधित्यकायां स्थितस्य सूर्यमन्दिरस्य शिलालेखस्तु ललितादित्यसमकालिकोऽस्ति । यस्येदमुद्धरणमधस्ताद् दीयते-

१ ....इतः यश्चायं........ ।

२ ....पद्मोद्भवहेतुतः........स्वान्नाभिपद्मोद्भवाद्ब्रह्मप्राप्तिकृतोद्य .... ।

३ ....व्याप्युग्रधामोत्करश्श्लाघ्यः कर्तुरपि प्रजां प्रतिदिनं कुर्वन्निवाशान्नवाम् ॥ वि .. ।

४ वादव्याप्तजगत्त्रयश्श्रितदयः कुर्वन्सदैवोदयम् । चक्राक्रान्तिसमुज्ज्वलः परिप .. ।

५ ....तो मुरारेरपि ॥ क्रान्तानन्तदिगम्बरात्करपरिव्याप्तत्रिलोकीतलाद्गोभिः .. ।
६ मतानि ज्ञानशशभृत्खण्डस्य धाम प्रभुर्भ्राम्यन्नृत्तविधायिनोऽपि जगतो यश्शंकर.. ।
७ ... श्रीमृताण्डस्य बिम्बं श्रीश्रीवर्मासपर्याहितमतिरकृतश्री ... सम्प्रतिराज्य ... ।
८ ... पश्रियोऽस्य त्र्यक्षोपेन्द्राब्जजानां प्रसभमपहृताशेषरक्षाश्रमस्य श्रीमा ... ।

परस्ताच्च यवनशासनसमये श्री शहाब-उद्दीनस्य राज्यकाले समुत्कीर्णः कपटेश्वरस्य (वर्तमानकूठिहेर) एको विशालः शिलालेखः काश्मीरप्रतापसंग्रहालये उपलभ्यते स्म यस्त्वधुना जीर्णोद्धाराय संग्रहालयाध्यक्षेण प्रदर्शिन्यां न निवेशितोऽस्ति । तस्मान्नोद्ध्रियते । एतदतिरिक्तं प्रमाण्डदेवस्य प्रतापपुरे (तापर) समुपलब्धेन मण्डपस्थेनैकेन शिलालेखेन प्रतीयते । असौ लौकिक-संवत् ३३ आषाढशुति १५-उट्टङ्कितोऽस्ति ।

जयसिंहस्य वाङ्गतारण्ये उपलब्धे शिलालेखे संवत् ८५ चैत्रशुति द्वादशीतिथिः निर्दिष्टास्ति यस्त्वेकस्मिन् शिलामण्डपे समुल्लिखितोऽस्ति ।

एवमेव संवत् २५ आषाढशुति ३ विजयकण्ठस्यैको शिलालेख एकस्मिन् मण्डपे लिखितोऽस्ति यस्मिन् शासकस्य नाम विनष्टम् ।

किं च पञ्चदशशतकीयस्य बडशाहनाम्ना प्रसिद्धस्य जैन-उल्लाउदीननृपस्य शासनकाले खानमोशाख्य-(वर्तमान-खोनमुह)ग्रामे हर्षेश्वरस्यापान्तर्वर्तिनः भुवनेश्वरस्यैकः शिलालेखोऽधस्ताद् अक्षरश उद्ध्रियते—

१ ओं सं ५ मार्ग शुति ५ शुक्रे ।
अनात्मा विश्वभूतात्मा निर्गुणस्सगुणश्च यः
सदसद्व्यक्तिरहितस्तस्मै सर्वात्मने नमः ॥ (१)
त्रिंशाधिके च शतभूतयुते कलस्य(लेः)
(कलिसंवत् ४५३०, खिस्ताब्दानुसारं १४२८)

२ याते सहस्रचतुरे शरदां बभूव ।
श्रीमत्सकन्दरसुतो धरणीधरेन्दु-
स्सतीसरे ह जयनोलबदेन शाहः ॥
अग्रहारे खगेन्द्रस्य खोनमोशे(मुषे) ह भूपतेः ।

३ द्विजेशे(श)शिवन्दकश्श्रीमान्देशाधिपतिरभूत् ॥
अत्राग्रहारे वणिजपूर्णकोऽभूत्सुतात्मजः
अनेन पुण्यवृद्धयर्थमाश्रमोऽयं प्रचक्रिरे

४ हर्षेश्वरस्य देवस्य योजनार्थमधस्थिता ।
भुवनेशस्य निकरे स्वर्नदी पापहारिणी ॥
गङ्गासमीपे परमेष(श)भक्त्या

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५ तप्तुं तपो ज्ञानपरोऽत्र योगी
जयाख्यपीडस्य नृपस्य दुर्गा-
त्समाययौ गम्यति सोदकाख्यः ॥

६ जित्वा मारं प्रबलतमसं बद्धपद्मासनस्थ-
स्स्मृत्वा ध्यानमलुठितपदमक्षयं सेवमानः
काले तेनैवेह कलियुगे लब्धमार्गश्शिवस्य ।

७ स सदाढ्यें किमपि न पदं सिद्ध्यते सर्वलोके ।
.....................चतुर्थेऽप्यथ वत्सरे ।

८ इह स्थाने प्रतिष्ठाभूत्पञ्चम्यां शुक्रवासरे ।
राकाभिद(ध)स्य वणिजपुत्रौ कन्थकनत्थकौ
स्थितौ तत्रास्ति लेखज्ञस्तक्षको गग्गकाभिद(धः) ॥

(एते सर्वे शिलालेखाः प्रतापसङ्ग्रहालये विद्यन्ते ।)

काश्मीरिका म्लेच्छाः पुरा यवनभाषानभिज्ञाः स्वमृतकानां स्मारकशिलापट्टकेष्वपि (tombs) संस्कृतेनैव संवदुल्लेखनपुरःसरं नामाङ्कनं कुर्वन्ति स्म, यस्योदाहृतिरूपेण कतिपये अंशा काश्मीरेष्वधुनापि लभ्यन्ते हारीपर्वतनिकटे प्रवरेश्वरमन्दिरे (वर्तमान-बहाउद्दीन ज़ियारत) ।

किं चानेकेषां तडागादीनां लोलाबप्रदेशवर्तिनां स्मारकभूताः शिलालेखा अपि संस्कृतेनैव लिखिताः सन्ति । यस्यावशेषाः परेपुरादिप्रदेशेषु सुस्पष्टं लभ्यन्ते, एतेऽपि जैन-उल-लाब्दीन-शासनकालिका एव ।

अतोऽधिकमुपलभ्यमानाः शिलालेखाः खुरहामा-वल्लराम-पहलगामादिप्रदेशेषु अद्यपर्यन्तं न सुस्पष्टं वाचिताः न चापि प्रकाशिताः सन्ति । एषु कतिपये स्नानागारेषु यवनैः क्षालनक्रियायै सन्निहिताः सन्ति । किंच वराहमूले (वर्तमान-बारामुला) कुशानकालीनः शिलालेख एकस्याश्वारोहिनः योद्धुः करवालेऽधः समुट्टङ्कितोऽस्ति यस्तु दुर्भाग्यवशात् केनापि वैदेशिकयात्रिणा ततश्चौर्येणापहृत्य अमेरिकाभ्यन्तरवर्तिकलिफ़ोर्नियाप्रदेशं प्रापितः, अद्यपर्यन्तं न केनापि प्रकाशितः ।

एतदतिरिक्तं श्रीनगरे वसन्तबागाभ्याशे वसन्तघाटस्य शिलालेखः सिंह(सिक्ख)-शासकस्य बसन्तसिंहस्याधुनापि विराजते यस्तु श्लोकबद्धोऽस्ति । किंच रघुनाथमन्दिरे जम्मूप्रदेशे दिवंगतस्य महाराजरणवीरसिंहस्यैको बृहच्छिलालेखो रघुनाथस्य पादमूले विद्यते यत्र रघुनाथमन्दिरस्य समस्तं कार्यजातं मूर्तीनां विवरणं च सविस्तरं वर्णितमस्ति ।

एवं च अमरनाथतीर्थस्यैको विशालः शिलालेखः श्री-अमरनाथस्तुतिपरकः राज्ञश्चन्द्रचूडस्य काश्मीरप्रतापसंग्रहालये विद्यते । एते त्रयोऽपि देवनागराक्षरैः टङ्किताः सन्ति ॥

POET NARASIMHA OF WARANGAL AND HIS LYRICAL POEM [SIDDHŌDVĀHA] KNOWN FROM INSCRIPTIONS

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Warangal has the privilege of being once the capital town of the entire Āndhradeśa for about a century from A.D. 1230 to 1323 during the reigns of Gaṇapatideva, Rudrāmbā and Pratāparudra of the Kākatīya dynasty. The glory of the town is fully evidenced by the numerous inscriptions, local records, literature and monuments. Pratāparudra, the last ruler of the dynasty, was the most powerful king who had very boldly repulsed the huge waves of the Mussalman invasions for no less than seven times and withstood the impact thereon. Besides his political greatness, Pratāparudra enojyed the unique honour of being a great scholar by himself and a patron of renowned scholars and poets Vidyānātha, Rudrabhaṭṭa, Tripurāntaka, Śivadevaiah and others. In the history of Sanskrit literature the Kākatīya period is marked in gold letters with the great rhetorician Vidyānātha, author of *Pratāparudrayaśobhūṣaṇa*. In the course of recent epigraphical researches, another poet by name Nṛsimha *alias* Narasiṁharṣi has been brought to light through about half a dozen inscriptions found in and around the Warangal Fort. He is not to be mistaken with another poet of the same name Narasimha, son of Gaṅgādhara and the author of *Kādambarī-kalyāṇa*, who also flourished under Kākatīya patronage.

On one of the slanting edges of the hillock called Ekaśilā in the fort in Warangal, is engraved in bold Telugu characters a Sanskrit verse which extols the greatness of Vīrarudra, the foremost king of the Kākatīya dynasty.

अठ्यादुर्वीमुदधिरशनामग्रणीः काकतीनां
विद्याशाली विदितविनयो वीररुद्राभिधानः ।
यात्राकाले विजितहरितो यस्य सेनागजानां
मध्ये कश्चिन्मलयशिखरी माल्यवान्मन्दरो वा ।। नरसिंह[र्षिः]

The war elephants of Vīrarudra are compared here with the mountains of Malaya, Mālyavat and Mandara. The king is described to be the foremost of the Kākatīyas and a learned sovereign of lofty character. At the end of the verse is engraved the name "Nṛsimharṣiḥ", obviously the signature of the author which clearly indicates that the poet flourished in the court of Pratāparudra (A.D. 1296-1323).

A verse inscribed on one of the *toraṇas* (gateways) of the fort describes the greatness of the poet by comparing him with the god Narasiṁha as follows:

अप्राप्तसभास्तम्भोऽप्यविपन्नहिरण्यकशिपुरपि ।
अविकृतमुखोऽपि दशसु प्रगल्भते रूपकेषु नरसिंहः ॥

God Narasimha came out of the pillar of the assembly hall with an abnormal face, killed Hiraṇyakaśipu and became famous for his ten incarnations; our poet Narasimha, without becoming dazed in the assembly (of scholars), without any difficulty for food and clothing (being well provided for) without his eloquence being affected, shines forth in the ten rūpakas (types of drama). This *Sleṣa* verse according to the inscription is quoted from *Malayavatī Gadya-Kāvya* which must be evidently one of the literary works of this poet.

We are not certain whether the poet actually wrote ten kinds of *rūpakas*, since none of them has unfortunately come down to us. It may simply be to denote his ability to write all the ten varieties of *rūpakas* that this statement has been made.

In a similar inscription engraved on another *toraṇa* (gateway) of the same fort it is stated that Nṛsiṁha, the author of works on Śāstras has written a work (a commentary) on *Ṛgveda* called *Ṛkcchāyā* (?) and *Kākatīya Carita,* of which 8 cantos were composed by him in a single day. Neither of these two valuable works is traceable now.

ऋक्छाया(?) रचिता निरर्गळगिरा येनाधिकस्थेयसी
शास्त्रग्रन्थकृता नृसिंहकृतिना हृद्ग्रन्थिगन्धच्छिदा ।
अह्नैकेन हि काकतीयचरिते तेनाष्ट शिष्टादृताः
काष्ठाघाटनिसर्गनिर्गतयशःसर्गेण सर्गाः कृताः ॥

On Siddheśvaraguṭṭa near Hanumakoṇḍa a Sanskrit work in a beautiful *Kāvya* style is incised but left incomplete with the description of Āndhradeśa and its paddy fields in 37 *niroṣṭhya* verses in which the poet has avoided the use of *pa-varga* letters (labials). But it cannot be said with certainty that this inscriptional poem forms the beginning of Narasiṁha's *Kākatīya-carita* mentioned above. His fanciful method of inscribing his works on stones here and there is the only basis for its being supposed to be the beginning of his *Kākatīya-carita*[1]. The following four verses are cited as specimen.

आन्ध्राः सन्ति गरीयांसः काञ्चनच्छायशालयः ।
यथा हाटकशैलस्य कटका रत्नशालिनः ॥

**It is interesting to note this verse is in Grantha characters, the significance of which is not known. The poet might have been educated in the Tamil region where this script was in use, or the political influence of the Kakatiya rulers over Kanchi might also be a plausible cause.

[1] *Ep. Ind.* Vol. XXXVI, pp. 209-215

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शालिसंरक्षिणीहस्तताळैः कङ्कणनादितैः ।
त्रासिताः किल गच्छन्ति यत्कीरास्तद्गिरा जिताः ॥
एकाऽस्त्येकशिलाख्यात्र नगरी या गरीयसी ।
सागरान्तां धरां कृत्स्नां श्रिता कान्त्या निरीक्ष्य(क्ष)ते ॥
लळाटेनार्धचन्द्रेण कृत्स्नचन्द्रैस्तथाननैः ।
यदङ्गनाः कळासक्ति निर्दिशन्ति निजार्जिताः ॥

In another place a few *gaṇas* regarding prosody are engraved on a stone pillar as quoted from a work named "Narasimhoktā gaṇāḥ".

क्ष्माशीतच्चिनसजाद्या स्वराजिरिष्येत सजराविरसा ।
नृसिंहोक्ता गणाः ॥

On a small hillock near Urus which is situated about two miles in the south-east of the Warangal railway station, two big inscriptions have been recently discovered. Both of them are in Sanskrit. One of them is in Nāgarī script and the other in Telugu characters of the 14th Century. The first one is incomplete and damaged due to incessant flow of rain water from the top of the hill, whereas the second is complete and in a state of almost good preservation. These epigraphs represent two separate poetical works of Narasiṁharṣi, son of Viśveśvara, the *rājaguru* (of Rudramādēvī), as known by the attestations at the end.

1. इति राजगुरु-विश्वेश्वरपण्डितसूनोर्नरसिंहर्षेः कृतौ योग[.....]प्रथमः सर्गः ॥
2. विश्वेश्वरसूनोर्नरसिंहर्षेः कृतिः ॥

The poem under notice is inscribed on a boulder facing the east of the said hillock. A panel measuring 4.05×2 metres is divided into three sections for the purpose of engraving. It contains a considerable number of errors and omissions for which the negligence of the engraver appears to be responsible. There are very few instances where works of literary value appear in inscriptions. The *Halāyudha Stotra* from the Amareśvara temple[1], which has copies of other texts, both printed and in manuscripts, and the Dhār Praśasti of Arjunavarman by Madana which is a *nāṭikā* named *Pārijātamañjarī*[2] are other examples of this type. The present work consists of sixty verses in *Śārdūlavikrīḍita* metre and two concluding verses in *Sragdharā* at the end.

The inscribed portion does not reveal directly or otherwise any title that can be ascribed to this little *kāvya* and for the sake of convenience the title *Siddhōdvāha* (the marriage of a Siddha) has been tentatively suggested on the basis of the contents[3]

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[1] *Ep. Ind.* Vol. XXV, pp. 175-185

[2] „ Vol. VIII, pp. 96-122

[3] A monograph under this title has been edited by the present writer and published by the Department of Archaeology and Museums, Andhra Pradesh, Hyderabad.

It is a small Śṛṅgāra-kāvya of lyrical nature which, like the famous *Meghasandeśa*, begins with the *viyoga* or disunion of a Siddha with his newly married lady, caused by a mischievous Yakṣa while the young couple were sporting on the sands of Trisrotas or Ganges.

> कश्चित्सिद्धयुवा समं दयितया त्रैस्रोतसे सैकते
> रागान्धो रममाण एव लिखिते कारण्डवानां पदैः ।
> द्रष्टुं दुर्विषहां मनोभवकृतां तां तामवस्थां तया
> विश्लेषं गमितः कुतूहलवता यक्षेण मायाविना ॥ (*v.* 1)

The Siddha suddenly notices to his surprise, the absence of his beloved on the bed. Being deprived of his mate, he goes about wandering and begins to narrate the recollections of his love with her, beginning from their first union.

> वाक्यान्येवमुवाच लक्ष्यरहितं पूर्वानुभूतीः स्मरन् ॥ (*v.* 4)
> मेरौ कल्पतरोः प्रसूनमधुना श्लिष्टेन सिक्ते तले
> सायं किन्नरयोषितां रसवशाद्गीतप्रसङ्गे सति ।
> आयातासि समं सखीभि [.....................]
> बाले प्राथमिकं तदेतदधुनाप्यालिख्यते चेतसि ॥ (*v.* 5)

One evening during a music party of the Kinnaras on Mt. Meru the Siddha sees for the first time the lady with her attendants and playmates. They both fall in love with each other. The mates notice her amorous looks and actions directed towards the young Siddha and make fun of it. In the meantime she is summoned (by her father) through a little boy to go home immediately. The interruption thus created by the boy is described in a beautiful simile.

> काले तावति काकपक्षकमुखेनोन्नद्धचूडामणि-
> बिभ्रन्मौक्तिककुण्डले श्रवणयोः कोऽप्यागतो बालकः ।
> नक्षत्रद्वयमध्यपातिशशिनो बिम्बं पुरोऽङ्गारकं
> व्याकुर्वन्वदनश्रियेन्दुवदनेत्वा(नां ता ?)माह्वयत्संभ्रमात् ॥ (*v.* 10)

The face of the boy between the two ear-rings studded with pearls on either side and the red crest jewel on the head is shining just like the moon between two stars facing the planet Mars. Again, the simile continues further to import the idea that the presence of the boy between the present hero and heroine is like Aṅgāraka, which is considered to be an inauspicious occurrence known as *Aṅgāraka-doṣa* in Hindu marriages.

She obeys though unwillingly, her father's order and leaves her lover with a heavy heart. The hero accompanies her up to the court-yard of the palace of her father. As the lady enters the interior of the palace he stands puzzled, not knowing whether to leave the place or do any thing else and with his senses mute.

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न स्थातुं न च गन्तुमन्यदपि वा नो कर्तुमीशोऽभवम् ॥ (*v.* 16)
तद्देशो नवरत्नचित्रिततलः स्पर्शानुकूलोऽनिलो
हाला हेमसरोरुहोदरदळेष्वापीतशेषाऽलिभिः ।
गीतं किन्नरयोषितां सुललितं कल्पद्रुमाः पुष्पिताः
याताः पञ्चभिरिन्द्रियैर्मम यथापूर्वं न भोग्यां दशाम् ॥ (*v.* 17)

At this stage the sun sets and the moon rises. Though it is a poetical convention to include the description of sun-set and moonrise in *kāvyas* the author here gives us by means of *vyaṅgya* the state of *viraha* of the hero and heroine drawing similarity in sunset and moonrise respectively.

कालेऽस्मिन् पुटपाकतप्तकनकाकारेण लोलाकृतिः
सन्ध्यामेघनवप्रवाळशयनं रागी समासेदिवान् ।
सन्तापादपराद्रिकन्दरझरीपाथःकणैराहतो
नेत्रैर्मीलयति स्म वासरपतिः पद्माकरच्छद्मना ॥ (*v.* 18)

सार्धं चेतनया समस्तजगतामस्तं गतो भानुमान्
व्यामोहेन समं तमांसि परितः काष्ठाः पदं चक्रिरे ।
वामैः कामुकलोचनैः सह ततस्तारागणाः पुस्फुरुः
कन्दर्पज्वलनेन साकमुदयं यातः कलानां निधिः ॥ (*v.* 19)

Here the use of the four synonymous indeclinables *sārdhaṁ*, *samaṁ*, *saha* and *sākaṁ* in the four lines respectively is worth noticing.

आदौ यावकपङ्कपाटलमथो बिम्बीफलाभं ततः
सद्यो लूनबहिष्पलाशविकचस्वर्णारविन्दोपमम् ।
पश्चादासवमत्तमाळववधूगण्डस्थलप्रक्रियं
बिम्बं चान्द्रमसं क्रमाद्विरहिणीवक्त्रोपमानं दधौ ॥ (v. 20)

A lady messenger despatched by the heroine comes to the disappointed hero waiting in the courtyard and explains before him the state of *viraha* of her mistress.

प्रासादे क्षणमङ्कणे क्षणमतो लीलासरस्यां क्षणं
क्रीडापर्वतके क्षणं प्रियसखीसंलापगोष्ठ्यां क्षणम् ।
शय्यायां क्षणमन्तरे क्षणमथ द्वार्वेदिकायां क्षणं
सा त्वामेव विचिन्वतीव बहुधा जातारतिर्वर्तते ॥ (*v.* 27)

Here the repetition of the word *kṣaṇam* for several times aptly suits her state of *arati* (aversion and restlessness), and *capalatā* (unsteadiness)

तिष्ठत्युच्चलति प्रयाति पुनरप्यायाति संभाषते
तूष्णींभावमुपैति पश्यति दिशः संमीलयत्यक्षिणी ।

उद्भ्राम्यत्यधिकं दधाति च धृतिं निश्चेष्टते चेष्टते
हा! कष्टं! मदनेन दारुणतरं किं किं न सा कार्यते ॥ (*v.* 28)
द्रष्टव्यः कथमेष दृष्टिसुभगः संभाषणीयः कथं
श्रोत्रस्वादु वचः सुसंहतवपुः संश्लेषणीयः कथम् ।
सान्निध्याविदितान्यवस्तुविषयः संसेवितव्यः कथं
सेत्थं त्वां प्रतिचिन्तयत्यहरहः पर्याकुला वर्तते ॥ (*v.* 32)

The *dūtī* also instructs him to come in the dead hours of the following night to the fort wall of the palace where he has to climb up into the lady's apartment by means of a rope which would be kept hanging ready for the purpose. The hero does accordingly. But to their misfortune while climbing, he is detected and produced before Kanakāṅgada, the father of the heroine. and cast into a prison, bound with strong ropes. After some days of inquiries Kanakāṅgada comes to know that the hero is a Siddha with respectable pedigree and character and therefore decides to offer his daughter to him in marriage. Then follows a description of the customary marriage ceremony and the honeymoon of the young couple. A few verses which describe the condition of a *mugdhā-nāyikā* when she meets her lover on the bed for the first time may be cited.

वेदीमध्यनिवेशितं हुतवहं कृत्वा विधेः साक्षिणं
  स्वेदाम्भःकणिकाभिरङ्गुलिमुखाद्भ्रान्ताभिरार्द्रस्तव ।
उद्भिन्नैररविन्दनाळसदृशीमाभां गतः कण्टकै-
  रूर्णैः कङ्कणवान् प्रवाळमृदुलस्पर्शो गृहीतः करः ॥ (*v.* 41)
तावत्त्वं विशनैर्मसान्यपरतामालोक्य संकोचितै-
  रङ्गैरंशुकवेष्टिताञ्चितपुरोभागैर्ह्रिया मीलिता ।
निद्राणेव निमील्य नेत्रकमळं तास्ताः कथाः शृण्वती
  शय्यान्तं भुजवल्लरीविवलनेनालिङ्ग्य जोषं स्थिता ॥ (*v.* 46)
ईष[त्सान्त्वन]भङ्गिबोधितमनास्त्वं कञ्चुकी(का?)कर्षणे
  प्रक्रान्तेऽथ नखक्षतादपि भयादत्यन्तमुद्वेजिता ।
कान्ते केवलमङ्गकैः पुलकिभिः कण्ठाक्तभावस्थिति-
  र्बाष्पोत्पीडवशान्निमीलितवती लज्जाकुले लोचने ॥ (*v*, 50)
नीवीबन्धनिवेशिते करतले निर्वेशतन्द्रावशा-
  दीषन्मीलनजातशारदनदीकाश्यानुकारे दृशौ ।
आसीत्ते सुखपारवश्यशिथिलं तद्धारणे व्यापृतो
  हस्तो घर्ममयूखमालिकिरणस्पृष्टप्रवालोपमः ॥ (*v.* 52)

Although the poet is more inclined to use simple words throughout his known writings, the above verse contains two exceptionally lengthy compounds,

क्रीडानन्तरमात्तसाध्वसतया निश्चेष्टितैरङ्गकैः
 क्लिश्यन्तीव कुचांशुकावृतमुखी वाक्यासहन्तीव(?) मे ।
मन्दोद्धूतपटाञ्चलेन सिचयेनावीज्यमाना मया
 लज्जामीलितलोचनैव शनकैर्निद्रां त्वमासा[द]यः ॥ (*v.* 53)

आलेपैर्गलितैर्नितम्बिनि दधौ निम्नस्थलेष्वासिता
 कण्ठः कम्बुनिभो मदीयवलयेनालिङ्गनैर्मुद्रितः ।
गात्रं ते परिवर्तनेन शयने वासस्तरङ्गाङ्कितं
 कान्तिः काचन सामिभुक्तजडिमा निद्रावसाने दृशोः ॥ (*v.* 55)

म्लानं चापि विकासि चापि वदनं वेणी घ वेष्टश्लथा
 भालश्च श्रमवारिमृष्टतिलको हासश्च संजायते ।
माया कापि च लक्ष्यते नयनयोः संमोदसंसूचिनी
 भुक्तासीति सखीभिरीरितरहःकृत्या भृशं लज्जिता ॥ (*v.*56)

जानीषे किमु कल्पपादपभवामापीय हालां त्वया
 क्रीडन्त्या मम सन्निधावपि निजामुन्मुच्य मुग्धे त्रपाम् ।
यद्यज्जल्पि[त]मुग्धजालविलपैरालस्यवद्भिः पदै-
 रङ्गैर्वा श्लथसन्निवेशलघुभिर्यद्यत्कृतं व्युत्क्रमात् ॥ (*v.* 57)

प्रत्यङ्गं नवचम्पकेष्विव रजो [व्यास?]र्ण्यं(?)मुन्मूलितं
 कान्तिर्नूतनकौमुदी कुवलयापीतेव जाता दृशोः ।
हासश्रीर्मुखपङ्कजे मधुमदादुत्कीलितेवाधिकं
 वैदग्ध्यं स्फटिकादिवेन्दुमुखि ते स्वान्तादहो बिम्बितम् ॥ (*v.* 58)

Since then they are in union till the Yaksha plays his mischief. In the end, after seeing the pitiable condition of the Siddha, the Yaksha makes the couple reunite and enjoy happiness.

योगानेवं प्रकारान्मुहुरनुभवतो हन्त मे विप्रयोगो
 जातः कस्मादिदानीं तव सुतनु हठादित्यमुष्मिन्ब्रुवाणे ।
यक्षः सन्दर्श्य रूपं तटिदुदयमिव स्वं विहायापि माया-
 मेताभ्यां दम्पतिभ्यां सहृदय[......]दाशिषं पूर्णकामाम् ॥ (*v.* 62)

There is similarity in certain points between this and the famous *Meghasandeśa* of Kālidāsa in the beginning and conclusion. Yet the theme differs in several respects. It is a novel idea of the present poet to make the hero intrude into the lady's palace by climbing up a rope, although the Siddhas by virtue of their divine origin are gifted with superhuman powers like flying in the air. So also the performance of a ceremonial marriage of the young couple and their nuptials are other fanciful adaptations of the poet taken from the customary marriages of the human

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society. The elaborate description of *Sambhoga-Sṛṅgāra* may also be noted. It may also be noted that the customary description of the physical beauty of the heroine is not given by the poet. The value of this little poem, in view of its excellent qualities such as refinement of thought, novelty in theme, chaste and mellifluous style, apt similes, and not in the least the metre *Śārdūlavikrīḍitā* with sweet and rhythmic expression may well be appreciated. It deserves a place among classical *Khaṇḍa-kāvyas* in Sanskrit.

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SANSKRIT CLASSICS AND INDIAN ART TRADITION

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The primacy of the literary word in the Indian artistic tradition has been much commented on. One of the criticisms which have been made against the plastic and the performing arts tradition is that it has learned heavily on the literary word. The traditional art historians and savants, on the other hand, have judged all pieces of artistic creation in movement, sound and colour with the yardstick of the literary word. So far few systematic studies have been done of the exact relationship between a Sanskrit text and the presentation or interpretation of that text through the plastic medium, the visual medium or the kinetic medium. Often enough, the relationship has been established on a general thematic level. All major works of Sanskrit literature, especially, those belonging to the tradition of the Kāvya, have provided inspiration and stimulation to the sculptor, painter, musician and dancer. Of special significance has been the interpretation of the epics, the *Rāmāyaṇa* and the *Mahābhārata* in the visual and the performing arts. Some studies have also been carried out on the part played by the theme as also the particular versions of the *Rāmāyaṇa* in the visual and the performing arts tradition of India and South-East Asia. The present paper attempts to make an analytical study of the part played by a medieval text—the *Gīta Govinda*—in the growth and development of the Indian artistic tradition in the visual and the performing arts. The paper analyses the literary composition from the point of view of its capacity of serving as a base for many schools of Indian miniature painting and several forms of music and dance prevalent in India.

A comparative study of the interpretation of the *Gīta Govinda* at different levels and in different art-forms is attempted. Through this comparative study which takes into account the pervasive effect of the *Gīta Govinda* in different parts of India, it is possible conclusively to illustrate,

(*a*) the creative use of the principle of the inter-relatedness and inter-dependence of the Indian arts (so eloquently formulated in the *Viṣṇudharmottara*);

(*b*) the principle of improvisation inherent in the concept of the *Vyabhicāri* (*Sañcāri*) *bhāva* of Indian aesthetics;

(*c*) the power of the *Gīta Govinda* completely to transform styles and techniques of music and dance in some regions.

The paper was illustrated through slides of miniature paintings and through tape-recordings of the musical interpretation of the *Gīta Govinda* drawn from different parts of India, and also with a sample of the *abhinaya* of one of its songs.

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SANSKRIT AND EDUCATIONAL IDEALS

PROF.: V. P. BOKIL, M.A.S.T.C.D., *Poona.*

Sanskrit is the most ancient language in the world known to man. It was spoken by the Indian Aryans for centuries before its script was found out. Naturally the Vedic hymns that flowed out from the mouths of the Aryan Seers were considered to be inspired utterances. The Aryan civilization which is reflected in the Vedic hymns is also known to be the most ancient in the world ; and it is very interesting to note that in the hymns some references are made to still more ancient seers and situations. From the history of their civilization we can get a clear picture of the life of the Aryans — their religion and education, their polity and society, their economy and industry, their arts and crafts. Sanskrit literature became vast and varied in course of time and the ideas and ideals decribed in the Vedic hymns were analysed and amplified, were sorted and systematised, were clarified and codified by great thinkers in it. Here it is proposed to note their educational ideals as can be gathered from the various references in Sanskrit books. It is hoped that this kind of review may give us some clue when we are at the cross-roads on the question of national education.

वेदोऽखिलो धर्ममूलम्

As our forefathers understood it, religion dominated practically every sphere of their individual, social and national life. The word actually used in Sanskrit for religion was 'Dharma', which was also taken to mean 'duty' or 'virtue'. Education began with Dharma in the Aryan society when Vedic hymns were sung by the seers. They were songs of knowledge (*Veda*) ; the common people heard them with interest and liked to learn them. Thus the Vedic seers began to play the role of teachers and priests. The common people learned to recite the hymns and also to do relevant actions to suit their meaning — salutations and offerings to the sun or fire. Small children in the locality could spend more time with the teacher than the grown-ups who had to do a lot of work and earn their bread. It was all oral work in education, because Sanskrit was the spoken language of the people (in which the Vedic hymns were composed) and its script was not formed yet ; and only Vedic seers knew the hymns. Naturally they were looked upon as leaders and teachers and they explained to the people that by saying those Vedic prayers and by giving offerings to the deities like the sun and the fire they could get health, wealth, long life, success in their undertakings and so on. The *āśramas* of Vedic seers became the first schools in this way. It has been recognised as a wonderful achievement of the Indian Aryans that they not only kept in tact the Vedic hymns by the word of mouth, but handed them down from generation to generation so carefully without losing a syllable of the text during several centuries.

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यज्ञोऽखिलः शास्त्रमूलम्

The Vedic hymns to God Fire were full of meaning. While reciting them the seers thought out the details of the sacrificial project : kindling fire, building a fire-place, collecting fuel, offering oblations, singing Vedic hymns, observing the stars for auspicious days and hours of sacrifice and other relevant actions. These actions led to the formulation of the four sub-Vedas (Upavedas) namely, *Āyurveda* (the science of medicine), *Dhanurveda* (the science of war), *Gāndharvaveda* (the science of fine arts) and *Vāstuveda* (the science of engineering) ; and of the six Vedāṅgas —*Śikṣā* (Phonetics), *Kalpa* (Procedure of rites and rituals), *Vyākaraṇa*, *Nirukta* (Etymology), *Chandas* (Prosody) and *Jyotiṣa* (Astronomy). These sciences emanated from the sacrificial project and then they became subjects of instruction. This is why there has been no opposition between religion and science in Indian education or between science and philosophy (that came to be formulated by the seers of Upaniṣads). By this time the age for children's initiation into learning (*Upanayana*) was fixed ; and as the Vedic literature multiplied, students began to specialise in the different branches of lore well suited to their innate capacities. They had to live in the *Āśrama* schools of the *Ācāryas* for several years as there was so much to learn. There they could understand the meaning of *Yajña* (sacrifice), which denoted the offering of some oblations to the fire and connoted the sacrifice of something small and trifling in the present times for the acquisition of something valuable and beneficial in the future.

सा विद्या या विमुक्तये

Education is both a science and an art ; and man has been its architect. Its aims and ideals, its aids and apparatus, its methods and manipulations, its social and individual aspects, its financial and follow-up problems and such other questions are considered and chalked out by teachers and educationists ; and thus an educational pattern is formed. Really speaking all adults in a society do the work of teaching and small children are always learning something through observation and imitation. Whatever is useful in life and whatever is likely to be helpful and beneficial to children is taught to them at home, at school, and in the society. The elders have their own ideas about happiness and greatness, virtues and values of life, art and industry and expect the children to be educated for the same. Thus education is known to be the dynamic side of philosophy ; because the ideals of life are formulated by philosophy and attained by education.

The concept of education is explained in some ancient Sanskrit books, which compares quite favourably with modern trends of thought. *Sā vidyā yā vimuktaye*, that is real learning which leads to liberation or emancipation. Here *Vidyā* or learning means education and liberation means the solution of a problem that presents itself to you on an occasion. Thus the education that you get must prepare you to solve the questions in life that crop up in your undertakings. Man is confronted in this world with questions that may be simple enough like 'crossing a street' and very difficult like 'realising his own spiritual nature'. His education should help him to solve them all successfully. Knowledge has been considered to be very useful in life, as can be seen from the following description :

ज्ञानं तृतीयं मनुजस्य नेत्रम् । समस्ततत्त्वार्थ-विलोकदक्षम् ।
तेजोऽनपेक्षं विगतान्तरायम् । प्रवृत्तिमत्सर्वजगत्त्रयेऽपि ॥

It is as good as a third eye to man. The difference between mere learning and development of intelligence was known to the ancients, as is clearly explained in this verse :

यस्य नास्ति विवेकस्तु केवलं यो बहुश्रुतः ।
न स जानाति शास्त्रार्थान् दर्वी पाकरसानिव ॥

So both knowledge and intelligence were expected of an educated person ; and the process of getting knowledge does develop intelligence.

अविद्यया मृत्युं तीर्त्वा विद्ययाऽमृतमश्नुते ।

The law-givers of the Hindus (new name for the Indian Aryans) divided man's life into four stages called *āśramas* : (1) *Brahmacarya* or Studentship, during which the young people were to get education ; (2) *Gṛhastha* or Householder's stage, during which the householder maintained his family by following some vocation and did his duty to the society and to the nation; (3) *Vānaprastha* or Forest-dweller's stage, in which the old householder retired to a forest with his wife, lived a simple life in a hut and thought out the values of the past life ; (4) *Saṁnyāsa* or Ascetic stage, in which the old man renounced all worldly ties, moved about from one holy place to another, meditated on 'Oṁ' and prepared for final emanicipation, *mokṣa*. A difference was noted between scientific subjects and philosophic subjects ; and the educationists said they both must be studied by the young : with a knowledge of the first group they can conquer the material world and with a knowledge of the second group they can enjoy the union of their individual soul with the universal soul — *i.e. mokṣa*. The words *parā* and *aparā* are also used by other writers to distinguish between the two kinds of lores.

Ramesh Chandra Datta has shown that in the Epic and Sūtra periods the Aryans had made great progress in the different arts and crafts, in social and natural sciences, in medicine and engineering, in mysticism and also in militarism. Sixty-four arts and crafts have been mentioned in Sanskrit books ; wonderful engineering works stood evidence to the mechanical skill of the ancient workers ; more than four hundred different surgical tools were used in addition to several herbal and chemical preparations to cure patients ; the Aryan warriors were wellknown for their bravery and use of war-weapons ; ideal kings and rulers of ancient India are still remembered and revered for their impartial justice and benevolent administration ; the Advaita Vedānta, Yoga-system and Hindu mysticism are still studied in the world, as they have stood the test of time and of modern science. This is enough to refute the charge that the Hindus cared more for the other world than

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this real practical life ; and this also shows that education in ancient India touched man's life at all points. The following verse indicates the importance given to the study of science :

अनेकसंशयच्छेदि परोक्षार्थस्य दर्शकम् ।
सर्वस्य लोचनं शास्त्रं यस्य नास्त्यन्ध एव सः ॥

The Hindus were sufficiently practical, never neglected their health and exhibited a realistic approach to life : (शरीरमाद्यं खलु धर्मसाधनम्). Kauṭalya's *Arthaśāstra* is a work on politics for guidance in all times (a deplorable neglect of which has reduced our present-day politicians to humility and misery).

In ancient Indian education social values were adequately recognised. The principles of Advaita Vedānta — namely, the individual souls are so many sparks of the universal spirit and the like — have explained them so clearly : (जीवो ब्रह्मैव नापरः). According to this philosophy, therefore, the relationship of universal brotherhood among all human beings is fundamentally established ; no laws are required for that.

एको देवः सर्वभूतेषु गूढः सर्वव्यापी सर्वभूतान्तरात्मा ।

All laws of morality and social amity are derived from this inner unity. This brotherhood in Hindu philosophy is not restricted to the people in India only : it embraces the whole human race, as can be seen from the common prayer sung by the ancient prophets :

सर्वेऽपि सुखिनः सन्तु सर्वे सन्तु निरामयाः ।
सर्वे भद्राणि पश्यन्तु मा कश्चिद् दुःखभाग् भवेत् ॥

This attitude of harmony and sympathy of the Hindus seems to be even more comprehensive than this : because they have shown sweet sentiments in the company of plant life, animal life and the five elements : सर्वं खल्विदं ब्रह्म. This Hindu attitude conduces more to peace and solace than that of a mere scientist.

English writers on education have said : "Man is born an animal and education transforms him into a human being." Of course, here the word 'education' means good education, education of the right type given by well-qualified teachers in favourable surroundings. It is also said that education is a panacea against all individual and social evils. This is half the truth ; because bad education or lop-sided education cannot be a remedy against any social malady. Only good education can mould individual minds properly and improve social life considerably. Our Sanskrit authors have said the same thing. The word *saṁskāra* has a very

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good connotation, including the development of inborn powers and also improvement of individual tendencies in conformity with the ideals of social and national life. Our ancients have laid great stress on *saṁskāra* to be given to the individual on sixteen different occasions during his life-time ; when the person receives blessings from family-deities, priests, relatives and well-wishers. They are sure to have a good effect psychologically, socially and spiritually. Some modern scientists in America have made experiments and proved that prayers, recitation of hymns and repetition of God's name produce healthy effects not only psychological, but also physical and chemical. "Well begun is half done" is a significant saying that supports this *saṁskāra* theory.

Modern educationists take into account two factors of education, namely, nature and nurture, otherwise called endowment and environment. The first of these is the heredity of the child, that is, whatever good or bad tendencies he has inherited from his parents and forefathers; and the second includes all that is done at home, at school and in the society to train him up in thinking, doing and collecting knowledge. Our ancients mention a third factor of education, namely, self-hood, which is the capital collected by the child in his previous births. They believed in rebirth (and orthodox Hindus believe in it even in these days) and took into consideration whatever the child brings with him in this life as the fruit of his *prārabdha-karma*. This has not been experimentally proved ; but it has been a fairly correct conclusion arrived at after careful observation of the achievements of children of the same parents brought up under the same environment and of great men like Śaṅkarācārya, Kṛṣna, Śivāji, Dhyāneshwar and the like. Belief in rebirth, though not yet accepted by modern science, seems to be socially and psychologically beneficial ; because people can be induced thereby to do good in this birth deeds with a hope of better luck and higher status in the next birth. That can be a sure process to reconstruct social life on a sound foundation. In this connection the following verse deserves consideration :

सुशीलो मातृपुण्येन पितृपुण्येन बुद्धिमान् ।
धार्मिको वंशपुण्येन स्वीयपुण्येन भाग्यवान् ॥

"A child becomes good-natured through his mother's merit, intelligent through his father's merit, religious through his family-merit and fortunate by his own merit." Here one's own merit is the product of one's own deeds in the past births ; and the first three can be included in heredity.

The teachers in ancient India were quite free to manage and conduct their schools. They owned some rent-free lands around the school-house, which they cultivated with the help of their students. That agricultural produce was mostly sufficient for the inmates of that *Āśrama*. If there was any deficiency the teachers and students used to go round and beg for food. The householders considered it to be their duty to give all possible help to guests, ascetics and those engaged in education. The princes and moneyed men occasionally paid visits to such *Āśrama*-schools, showed their respect and appreciation to the *Ācāryas* and gave them grants in coin or kind. For such help the princes or other visitors did not lay down any conditions or restrictions ; and the *Ācāryas* enjoyed full freedom in the *Āśrama* so long as the work of education continued satisfactorily. That freedom was not misused by the *Ācāryas*, because it was their religious duty to study and to teach. The *Ācāryas* met in congregations, compared their notes, discussed their difficulties, tested their advanced students and appreciated merit and research-work. In this way satisfactory standards of education were maintained even in the absence of Government control. Some *Āśrama*-schools or *Guru-kulas* created their own traditions of learning. **'यावज्जीवमधीते विप्रः'** :—The Brahmin or *Ācārya* was expected to continue his own studious habits till death. Naturally he became an expert in his subject ; and he would then make research and compose a treatise on it. It was then tested in a conference of educationists and, if it stood the test, the author was honoured ; and then his work could be included in the curriculum. That was how Sanskrit literature multiplied in its different branches. The teachers were a devoted class, having no other ambition except learning and teaching :

आचिनोति च शास्त्रार्थान् शिष्यान् ग्राहयते सुधीः ।
स्वयमाचरते चैव स आचार्य इति स्मृतः ॥

Some of those teachers, of course, aimed at the spiritual goal of life — *i.e.*, union of the individual soul with the universal spirit ; and even in that case they did not neglect their duty in the school. To meet such teachers and to serve them and to learn from them students came from long distances. There was no question of the payment of fees for education in those days ; becuause **सेवया विद्या** (acquisition of learning and wisdom by service to the *Ācāryas*) was the accepted principle. The students were prepared to live with the Guru long enough till his satisfaction ; because it was also an accepted principle that " education is a slow process ".

शनैर्विद्या शनैः पन्थाः शनैः पर्वतलङ्घनम् ।
आचार्यात् पादमादत्ते पादं शिष्यः स्वमेधया ।
पादं च ब्रह्मचारिभ्यः पादं कालक्रमेण वै ॥

The most important principle of education was " teaching by example rather than by precept "; the *Ācāryas* were, not only highly learned and intelligent, but men of character, from whose conduct the students learned much. The contact between the two was very close, as they lived together for several years practically like members of the same family.

The methods of teaching in those *Āśrama*-schools were based on individual attention. The number of students per teacher was small enough and he could easily look at each one of them, judge his capacity and adjust the lesson to it. Whatever was taught by the teacher was to be thoroughly learnt by the student ; it was quite necessary in the beginning, when there were neither written nor printed books, and later it became a traditional method even when books came into use : एकः शब्दः सम्यग् ज्ञातः सम्यक् प्रयुक्तः स्वर्गे लोके कामधुग् भवति; this was the general understanding. Still the learning by heart was not done by the students before the meaning of the text was known. The teachers and advanced students were called पदवाक्यप्रमाणज्ञाः; they were well versed in "grammar, *mīmāmsā* and logical arguments". Very intuitively the teachers could realise that, if the student knew even one subject thoroughly well, his powers of understanding would be developed thereby and that those powers could be used by him in studying another allied subject. This principle of "transfer of training" has been experimentally proved to be true by modern educationists. The student was expected to exert himself sincerely in learning his lessons and to concentrate on them. He was not to run after worldly pleasures (सुखार्थिनः कुतो विद्या) nor was he to waste his time in meaningless and frivolous activities, because "education was a serious affair". In addition to such concentration on learning the student spent some time regularly at stated hours in the day in worshipping God, offering oblations to him, saying prayers and invoking blessings. It was thus known to the ancients intuitively that "more things are wrought by prayer than this world dreams of": सर्वं हि तपसा साध्यम् । The dialogues in Upaniṣadic works show how questions and answers and concrete illustrations were used by teachers and students in those *Āśrama* schools. The advanced students often helped the teachers in looking after the lessons of the beginners and juniors. This was later developed into the monitorial method in Popular Elementary and Missionary schools. These methods of teaching were quite successful, as can be seen from the results in the social and national peace and prosperity and as can be judged from the reports of the Chinese and European travellers ; and that, too, in the absence of scientific and experimental apparatus (which is available to modern educationists).

विनीतवेषेण प्रवेष्टव्यानि तपोवनानि नाम ।

The atmosphere in and about the *Āśrama* school was quite austere and of disciplinary value. It was an educational colony, where the teachers and the students lived together, prayed together, studied together and worked together. Nobody could disturb them in their daily routine because it was the king's duty to give them protection. Nor were there any social disorders (like strikes) to distract their attention from their undertaking. Radio-broadcasts and cinema pictures were not known to them ; and hence the work of education could go on quite peacefully and regularly. The teachers and the students were there as good as members of the same family without any mercenary idea in their relationship. The former took care of the latter in all circumstances and at all times just like their own children ; and the students, too, served and respected their teachers just like their own parents. The dicispline in the *Āśrama* was thus based on love and respect, the teachers' love for the students and the students' respect for the teachers ; and both the sentiments were the sacred aspects of religious duty.

अभिवादनशीलस्य वटोर्विद्याव्रतस्य वै ।
चत्वारि तस्य वर्धन्ते आयुर्विद्या यशो बलम् ॥

In those circumstances no question of indiscipline could arise ; and sacarcely any occasion for punishment.

The *Ācārya* was a model of humanity before the students, who were inspired by his example to work towards a high goal of life. शीलेन सर्वं वशम् । शीलं परं भूषणम् । Naturally, cultivation of virtue and acquisition of learning were their chief pursuits. Bodily pleasures were not thought of, though regular efforts were made to maintain health, to sustain growth and to gain strength; because the body was considered to be a boat, with the help of which the ocean of this worldly existence was to be successfully crossed.

महता पुण्यपण्येन क्रीतेयं कायनौस्त्वया ।
तया तीर्त्वा भवाम्भोधिं प्राप्तव्यं परमं पदम् ॥

That was the high spiritual ideal before the students whose character-formation was the ultimate aim of education. The divine qualities that constitute character have been clearly mentioned in the 16th chapter of the *Bhagavadgītā* :

अभयं सत्त्वसंशुद्धिर्ज्ञानयोगव्यवस्थितिः ।
दानं दमश्च यज्ञश्च स्वाध्यायस्तप आर्जवम् ॥
अहिंसा सत्यमक्रोधस्त्यागः शान्तिरपैशुनम् ।
दया भूतेष्वलोलुप्त्वं मार्दवं ह्रीरचापलम् ॥
तेजः क्षमा धृतिः शौचमद्रोहो नातिमानिता ।
भवन्ति सम्पदं दैवीमभिजातस्य भारत ॥

The daily routine of the students was so arranged that they could automatically imbibe useful knowledge, cultivate these divine qualities and have no temptation for frivolous thoughts or mischievous acts. They were not to neglect their duties in practical life ; and still they had to strive for the spiritual ideal. The acts in practical life were to be considered as so many flowers, with which the all-pervading God was to be worshipped :

स्वकर्मकुसुमैरर्च्यते सर्वसाक्षी ।
यतः सर्वाणि भूतानि येन सर्वमिदं ततम् ।
स्वकर्मणा तमभ्यर्च्य सिद्धिं विन्दति मानवः ॥

Two aspects of Hindu religion were explained by great writers on the subject : (i) अभ्युदयरूपो धर्मः—religion leading to prosperity in life ; and (ii) निःश्रेयसरूपो धर्मः—Religion leading to the final goal of life, *mokṣa*. Most people long for success and prosperity in life : health and strength, long life, happy home, wealth and good children, fame and high status in society and the like. They should do their duty regularly and carefully, observe all moral rules scrupulously

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work at their vocation zealously, earn wealth honestly and worship the family-god very devoutly. Then they are sure to be successful householders and can enjoy all worldly pleasures. They can achieve great deeds and make valuable contributions to social or industrial or national greatness. These people follow the first aspect of our religion (अभ्युदयरूपं धर्मम्). Therefore sage Vyāsa has said :

धर्मादर्थश्च कामश्च स किमर्थं न सेव्यते ।

Very few persons really think of *mokṣa,* know its genuine nature and strive for it earnestly ; because it means complete emancipation, which includes renunciation of all bonds — social relations, home relations and even bodily relations. They may leave the society easily and run away from the home readily ; but they find it very difficult to cast off the physical exterior.

मनुष्याणां सहस्रेषु कश्चिद्यतति सिद्धये ।
यततामपि सिद्धानां कश्चिन्मां वेत्ति तत्त्वतः ॥

This view about emancipation is quite true. Śaṅkarācārya says—

प्रव्रज्याऽपि द्विधा स्यान्नियमितमनसां गेहतो देहतश्च ।

"The ascetics have not only to leave the home but to cast off the body also." To attain this ultimate ideal the aspirant has to train his mind for a long time and go through the different stages outlined by experts :

(i) नित्यानित्य-वस्तु-विवेकः । (ii) शमदमादिषट्सम्पत्तिः । (iii) इहामुत्रफल-भोगविरागः । (iv) मुमुक्षुत्वम् ॥

when the mind is throughly trained through this graded course, he finds out a Guru, serves him and acts up to his advice very devoutly and assiduously. This path to emancipation is open to each and all, to men and women, to the rich and the poor. Whoever feels a genuine longing for it is free to resort to it even directly from studentship (*brahmacarya*): यदहरेव विरजेत् तदहरेव प्रव्रजेत् । This *mokṣa* has been described as the best and ultimate goal of life (धर्मार्थकाममोक्षाः). These two paths of the Hindu religion are not quite exclusive of each other : one can switch on from the first to the second any time; because it is a question of mental culture. Asceticism is both physical and mental ; mere physical asceticism is a farce; and what is essential for spiritual life is mental asceticism. Eminent writers like Śaṅkarācārya have attached greater importance to the latter, *Vidvatsaṁnyāsa* than to the former, *āśramasaṁnyāsa*.

Advanced students in the *Āśrama* schools got an idea of the two-fold Hindu religion and were given necessary instructions by their *Ācārya* for their future life. These instructions sound like a convocation address : धर्मं चर। सत्यं वद। स्वाध्यायान्मा प्रमदः...; and they refer to the students' private life and study, family-responsibilities, social duties and other relevant questions. The *Ācārya* purposefully warned the students to ignore his defects and to imitate his good qualities and deeds. Great stress was laid on the continuance of the tradition of the *Āśrama* school, which had a good effect on raising the tone of social life. Thus

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it will be seen that the educational ideals explained in Sanskrit works were not one-sided or lop-sided ; but they were all-round and touched man's life at all points. The psychology as known to our ancient prophets was deeper than what is explained by modern psychologists of the west. The former have spoken of आत्मा मनसा संयुज्येत । मन इन्द्रिंयेण। इन्द्रियमर्थेन । That is how man gets knowledge of the world. But the western psychologists do not believe in the soul (*ātmā*) and consider the mind (with its different abilities) to be the final power. Lately however, they have been speaking of the sub-conscious mind, the super-conscious mind and also the cosmic mind. They also recognise now the extra-sensory power of the mind and are studying our Yoga system. They are making many experiments (on telepathy and the like) and explaining them in "Parapsychology ’. It is also refreshing to note that modern scientists have said that the more they discover, the more are the fresh fields for exploring. They have also found out that matter as such does not exist differently and that all is spirit, pervading the whole universe. Is this not the same as ब्रह्म सत्यं जगन्मिथ्या जीवो ब्रह्मैव नापरः ?

This spiritualistic philosophy (as formulated by our ancient prophets) seems to be quite acceptable in modern times. It rises above all sectarian religions and embraces the whole humanity. The word 'spirit' gets its meaning from the Greek root that means " breathing ". Thus philosophy can apply to all those that breathe and this shows the usefulness of deep breathing in the process of God-realisation, as explained by our ancient sages and saints. The universal spirit pervades the whole world and keeps it in working order. Its sparks are in the hearts of all men and keep them alive and supply them the necessary energy for work. Thus all men are brothers to each other, being children of the same God or Universal spirit. In the modern times of democratic life this principle of Universal brotherhood should be greatly conducive to peace and happiness in the national and also in international matters. This idea of oneness or unity is sure to result in good morality ; but difference or duality generally leads to enmity. When men are conscious of mutual oneness, they will certainly behave peacefully with each other. Then they care more for spiritual goods than for material goods, their need will not grow into greed ; and then struggle will be rare in practical life. Consequently the atmosphere will be more favourable to peace and happiness. It is not expected that people will all be saints or *yogins* by observing the principles of our spiritualistic philosophy in life and education ; but their conduct in practical dealings will surely be conducive to peace, as they will become more introspective. Nor is it expected that the observance of this philosophy will solve all problems of modern life (like the struggle between capital and labour) as if by the touch of a magic wand ; but the general attitude of sympathy (that will be created by it) can help to a considerable extent their peaceful solutions. This philosophy of ours stands for one world, one mankind and one God ; and it can inspire men to deal with men as human beings. It can provide the necessary vision and wisdom to use rightly the bountiful wealth and the terrible weapons supplied by science.

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ADVAITA VEDĀNTA AND MODERN PHYSICS

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In this paper an attempt will be made to prove how the findings of Modern Physics go to support the tenets of Advaita Vedānta regarding consciousness and matter and the nature of the physical world. The discussion anticipates a knowledge of the fundamentals of both Vedānta and Modern Physics as it is not possible to go into details within the prescribed range of the paper.

The findings of Modern Physics regarding the nature and structure of matter of physical universe may be thus summed up :—

(i) An atom is not a hard chunk of matter. The greater portion of an atom is simply empty space.

(ii) The remaining portion of an atom consists of various electric charges, viz., electrons, protons, neutrons, positrons etc.

(iii) Matter and radiation are identical in substance, matter and energy are equivalent. Matter is energy and *vice versa.* Matter is bottled up energy whereas radiation is free energy . Energy concealed is matter and matter released is energy.

(iv) Matter or Universe is subject to change and decay, beginning and ending. An atom is also subject to birth and decay.

(v) The Universe is gradually and steadily heading towards complete disorganisation or thermo-dynamic equilibrium.

(vi) The total energy of the universe remains constant.

(vii) The principle of indeterminacy shows that we can never know the realm of nature exactly and completely.

(viii) The electrons possess double groups of properties, namely, wave-properties and particle-properties. Eddington coins a new name "wavicle" to mean the combination of these double properties.

Thus the New Physics presents two pictures of the ultimate constituent of matter, the particle-picture and the wave-picture. But none of them, taken singly, is the complete presentation of truth about the world.

The findings of Modern Physics summed up in the foregoing lines have led famous scientists like Max Planck, James, Jeans, Eddington and Haldane to conclude that the ultimate cause of matter cannot be matter, becaue matter must have a cause. Matter is derived from non-matter or consciousness. "I regard matter

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as derivative of consciousness,' says Max Planck. In the same breath Eddington makes a categorical assertion, 'Matter is derivative of consciousness', in the very opening line of one of the chapters of his book, *The nature of the Physical World.*'

Jeans says that Old Physics regarded the universe as a great machine whereas New Physics regards it as an expression of a Great Mind. Observes Einstein: "The Great Scientists of all centuries of our civilisation have paid tribute in some measure to the Power or Principle at the back of the universe, the Titanic First Cause that still mothers creation."

But the conclusion of Eddington, Planck etc., that matter is derived of Consciousness raises a number of difficult problems. The extreme subtlety of the relatively final constitutents of matter has made it possible for the Scientists to trace the origin of matter to a non-material substance. The wave-picture of matter is a purely mental construct to understand the inherent subtlety of matter. It is also true that matter in the final analysis seems to fade away into something unknown beyond space and time. In the ultimate analysis matter, in the language of Jeans, "de-materialises." All material bodies from the very dust to hundred-storeyed mansions are nothing but charges of electricity in the final scientific analysis. Thus, speaking from this angle of vision, 'with huge cost, we have purchased huge mansions', that is, as Einstein finely puts it, 'airy nothings'. Hence it is that Eddington observes: "What we have ultimately come down to is waves, waves, waves"[1]. Jeans writes: 'We live in a universe of waves and nothing but waves'[2].

The conception of Eddington about the final cause of matter needs amplification because his view is strikingly similar to the Vedāntic theory of Consciousness or Being as the final cause of the world-show. Eddington asserts in clear terms that the basic stuff of the universe is mind-stuff. He writes: "The mind-stuff is not spread in space and time-these are the parts of the cyclic scheme ultimately derived out of it"[3]. Thereby he implies that the origination of the physical universe can be traced to this mind-stuff. This "mind" is spiritual and is also the originator of individual minds. By way of clarification he adds: 'It is sometimes urged that the basal stuff of the world should be called "neutral stuff" rather than "mind-stuff" since it is to be such that both mind and matter originate from it.'[4] This passage leaves no room for misunderstanding his stand. He maintains that the basal mind-stuff is the creator of both matter and non-matter which includes mind or spirit. As his mind is spiritual in nature, he visualises the entire creation as the expression of this spiritual substance. 'I assert', remarks Eddington, 'that the nature of all reality is spiritual—not material or a dualism of matter and spirit'[5]. But he does not want to use his own words, 'materialise or substantialise mind'. He simply perceives in matter a differentiated expression of the mind-stuff and does not recognise any

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1. *The Philosophy of Physical Science*, p. 110.
2. *The Mysterious Universe*, p. 99.
3. *The Nature of the Physical World.*
4. *Ibid.*
5. *New Pathways in Science*, p. 319.

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insuperable barrier between them. Thus he envisages matter as a part of the great mind-stuff and to him, mind and matter are ultimately identical. As shown above he does not advocate the eternal dualism of mind and matter. Falling back on the recent findings of New Physics he holds that in the final analysis matter cannot be described as material in nature and content. Thus Eddington strikes off the line of demarcation between mind and matter to facilitate the emergence of matter from non-matter directly. He compares the spiritual reality with the ocean and the physical universe with the waves of the ocean.

Vedānta also maintains that the Reality is spiritual in nature, it is neither material nor a dualism of mind and matter. Śaṅkarācārya, the hero eponymous of Advaita Vedānta, compares the ultimate reality with the ocean and the names and forms of the world-show with the waves that rise and dissolve in the immense bosom of the ocean. Unwittingly does Eddington institute the same comparison. Vedānta too holds that Īśvara or mind-stuff is the creator of both matter and mind. But unlike Eddington, Vedānta neither traces the origin of matter directly from the mind-stuff or Īśvara, nor sees in matter the direct manifestation or modification of the spirit-stuff. Vedānta does not strike off the line of demarcation between spirit and matter. Adcording to Vedānta, to hold matter to be the direct modification of consciousness or spirit is most illogical and unscientific. The distinction between spirit and matter cannot be wholly wiped out. Matter however subtle and refined it may be, can never lose its criterion of inanimacy and other material characteristics wholly even in its ultimate stage. Physics does not altogether deny the objectivity of matter which exists independently of our mind. The particle-picture of matter which is fully material can never be dissociated from the its wave-picture. Thus the physical universe can never be the direct modification of Consciousness, if we accept the supposition it will impose on pure consciousness the inherent grossness and the resultant limitation of materiality. In that case consciousness or spirit is denied its essential non-material character.

This stand vitiates the doctrine of causality as well. In case of modification the passage from the cause to the effect is a passage from sleeping to waking, from latency to potency, from implicit to explict. The cause is the effect implicit whereas the effect is the cause explicit. Hence to evolve matter directly, consciousness must contain in it the germ of matter in a potential form. Eddington's view of direct emergence of matter from consciousness has to face this critical situation. It imposes materiality of the nature of consciousness. The stand of Vedānta on this issue steers clear of the difficulty and provides us with the only possible solution. Vedānta holds that the material universe is not the direct modification but the indirect outcome of consciousness or God, and that the world is an appearance. By positing these factors Vedānta establishes the reality and purity of consciousness or spirit which is one without the second and explains the emergence of matter from consciousness without encroaching upon the essential characteristics of both spirit and matter. The medium through which consciousness operates for the emergence of matter is termed 'Māyā' in Vedānta. Vedānta holds that the pure consciousness or Brahman is an Absolute, Omnipoent, Omniscient and all-pervading Reality and

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nothing can exist independent of or minus from It. "Creation" says Śaṅkara, "is only temporary imposition of name and form, 'nāma' and 'rūpa' on the pure consciousness or Supreme Soul which is the only, true reality."[6] Consciousness is at once the material cause and the efficient cause of the Universe. By itself it is the efficient cause and through 'Māyā' or energy it is the material cause. According to Śaṅkara, Māyā or energy is rooted in the final cause (Brahman or consciousness) and the effect (creation) is rooted in the energy (Śakti or Māyā)[7]. Observes Swami Vivekānanda: "According to Śaṅkara God is both the material and the efficient cause through Māyā, not in reality"[8]. Creation or Universe is the direct modification of Māyā or energy, not of consciousness. Thus by tracing the origin of matter (universe) to consciousness via Māyā—by holding the universe to be an appearance, Vedānta shakes itself free of the fallacy committed by some Scientists who maintain that the origination of matter can be directly traced to spirit. "The effect is unreal, is an appearance; hence it cannot vitiate the purity of its cause (spirit). The conscious principle is not contaminated by the universe which hangs on consciousness just as a magician is not affected by his own magic."[9]

This doctrine of Vedānta throws a great deal of light on the truth of the findings of Neo-physics about the ultimate form of matter of creation. It is an admitted fact to-day that before the searching analysis of Science matter has revealed its inner essence and its character of appearance. Matter tends to become unknowable. Again, the inscrutability of matter cannot be the ground of a slipshod logic that matter is mind. Modern physics has stumbled on the Vedāntic conclusion. The results of the observations and experiments of Science show that matter is not mind but that matter is definitely an appearance. We must be on our guard not to confuse the concept of appearance with the concept of sheer illusion or pure mentalism bereft of object-content.

Both Vedānta and the Neo-physics do not support the mentalism or idealism of the Berkeleian type which is generally termed subjectivitism. According to Berkeley the world of so-called matter or material bodies has no independent existence of its own without a seeing or perceiving mind. Thus an object ceases to exist when it is not perceived by anybody. Thus the so-called external reality is bereft of substance or objectivity and is essentially spiritual in nature. The latter part of Barkeley's contention *viz.*, the spiritual nature of reality bears affinity to the philosophical trends of Vedānta and Neo-physics. But the tenets of Vedānta and physics do not lend support to his assertion that existence of the external world is completely dependent upon the seeing mind. To Vedānta the world is not merely a dream or sheer projection of the mind. The Vedāntic doctrine of Māyā is often misunderstood and wrongly interpreted as to suggest that the phenomenal world is wholly an illusion like dream, a pure mental projection. This is highly misleading. Vedānta does never deny the objectivity or relative reality of the world. Had

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6. *Brahma Sūtra Bhāṣya*, 2.1.4
7. *Ibid* 2.1.18.
8. *Complete Works of Swami Vivekananda*, Vol. II, p. 341.
9. *Brahma Sūtra Bhāṣya*, 2.1.9.

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Vedānta denied the objective existence of the world there would have been difference in the ultimate philosophical views of Vedānta and the Yogācāra School of the Buddhist philosophy : whereas Vedānta has refuted the view of the Yogācāra school of Buddhist philosophy that upholds pure mentalism or subjectivitism. The phenomenal world, according to Vedānta, is not unreal in the sense in which a hare's horn or mare's egg, crocodile's milk etc., is unreal. The changes do actually appear, and as appearances they possess all the reality that can belong to a change.

The Absolute cannot and does not change and hence the changes that appear cannot be the changes of the Absolute. So from the standpoint of the Absolute, change is unreal and is a mere appearance. But in the world of phenomena every change is real, and there is fixity of order and system amongst the changes themselves. Not to speak of the reality of the phenomenal world Vedānta admits the temporary nature of reality in cases of erroneous or sublated cognition even when a rope appears as a snake or a nacre as a piece of silver. Vedānta maintains three grades of reality,—Vyāvahārika-sattā or phenomenal reality, *i.e.*, the reality of the world, Prātibhāsika-sattā or imputed reailty, *i.e.*, the reality of the snake, Silver etc., in cases of sublated cognition, and Pāramarthika-sattā, the fundamental reality that belongs to Pure Consciousness alone. Śaṅkara rejects the theory that nothing exists, neither matter nor mind. According to Vedānta that alone is termed non-real or non-existent which never exists – a complete non-entity like a mare's egg., square circle, hare's horn, crocodile's milk or flower that blooms in the firmament. These are the stock examples of non-real entities in the Vedānta philosophy. Unlike these non-entities the world clearly appears to us. We see it, feel it, smell it, touch it. Moreover, the world, unlike the non-entities referred to above, possesses practical usefulness and temporal value.

It is interesting to note that Max Planck, the great physicist, also conceives of three grades of existence. In his book *The Universe in the light of Modern Physics* he thus describes the three different kinds of world: "(i) the world of the senses or the tangible world : (ii) the world of physics or the hypothetical world; and (iii) the real world of intangibility." (Page 10). "The world of senses or the tangible world is the world based on sense perception." The world of physics is a deliberate hypothesis put forward by a finite human mind, and as such , it is subject to changes. Planck's world of senses or the tangible world is the *Vyāvahārika Sattā* or phonemenal reality of Vedānta. Planck describes the real intangible world as "the world that lies beyond our senses and is independent of them." (Page 9). Thus Planck's real world is no other than the *Pāramārthika Sattā* or fundamental reality of Vedānta. In page 15 of his book under reference Planck maintains: "As the view of the physical world is perfected, it simultaneously recedes from the world of senses and approaches the world of reality. The history of physics shows that whenever the problem of the construction of physical theory has been solved, it has been done on the assumption of a real world independent of our senses, and it seems reasonably certain that this will continue to be the case in future. Plank, Jeans, Eddington, Haldane, Heisenberg etc. clearly admit that the world apprehended by scientific experiments and observations is only an appearence, not the reality.

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Śaṅkara advances many convincing arguments to refute the Buddhistic doctrine of mentalism which holds the world to be a dream, a sheer projection of the mind, an illusory product of human fancy bereft of any objective reality or matter-stuff. Śaṅkara's arguments are embodied mainly in his commentary on the *Brahma Sūtra* and the *Bṛhadarāṇyakopaniṣad*. Amongst the many arguments adduced by him four important points stand out pre-eminently :

(i) No one can deny the existence of external objects becaue they are perceived to exist by all persons. If we do so it would give the lie to our immediate experience.

(ii) If the immediate experience is disbelieved the reality of mental states cannot be believed in, and such a state of affair will result in complete chaos.

(iii) To hold that ideas of the mind illusorily appear as external objects is meaningless unless at least something external is admitted to be real. The clause 'appearing as external objects' is a misnomer.

(iv) There is a vital difference between dream-objects and perceived objects. External objects perceived during waking stage cannot be said to be unreal so long they are not contradicted.

Observes Śaṅkara : 'The knowledge of objects goes to confirm the existence of external objects because knowing cannot be identified with objects.'[10] The refutation of the Buddhistic theory of subjectivitism by Śaṅkara clearly proves the externality of the world to the thinking object.

Like Śaṅkara, Jeans also in his *Physics and Philosophy* critically examines the Berkeleian subjectivitism in the light of recent discoveries of physics. This type of subjectivitism, like the Buddhist School of mentalism or Yogācāra, supposes all objects to be the aggregate of their secondary qualities only. Criticising this view Jeans says :....... "physics gives no support to this division of qualities into primary and secondary—Berkeley's argument falls through his not seeing that each quality such as redness must have primary ingredients as well as its alleged secondary ingredients."[11]

Jeans proves that the quality of redness has both objective redness and subjective redness. He also thinks that the theory of atomic radiation does not lead us to subjectivitism. Curiously enough, Jeans has unwittingly advanced several arguments to refute mentalism, arguments advanced by Śaṅkara a thousand years ago. Śaṅkara says that a morsel of food will have no taste if it has no objective reality. From our experience we know it tastes sweet or bitter or sour as the case may be. Though it is relatively real and has no ultimate reality, nevertheless, it makes itself felt and we cannot deny its external existence. In the same strain does

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[10] *Brahma-Sūtra-Bhāṣya* 2-2-28.

[11] *Physics and Philosophy*.

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Jeans observes: "Being hit by a golf ball hurts as much now that we know it is little more than empty space ; its material properties have not been demolished."[12]

According to Advaita Vedānta matter or the world is relatively real ; hence it cannot be called wholly unreal or ' Asat '. Again it is not eternal, it lacks fundamental reality which belongs to Brahman or spirit alone: hence it cannot be termed real or ' Sat ' in the true sense of the term. Thus we can ascribe neither reality (Sat) nor non-reality (Asat) to the nature of the world. Hence Śaṅkara calls the nature of the world 'Anirvacanīya' or inexpressible. Be it mentioned here that the term ' Māyā , or ' Mithyā ' or illusion used by Śaṅkara to describe the nature of the universe always means inexpressibility (of nature) and does never signify non-reality of the physical world.

Let us now turn to Science. Modern Physics also fails to describe the true nature of the world in terms of reality or non-reality.

The wave-picture of matter may be a mental construct but it does not and cannot represent the whole truth about the nature of the world or matter because the particle-picture of matter is inseparable from it. The wave-picture leads us to the region of inmateriality shown of matter-stuff but the particle-picture drags us from behind and says, 'No, the world is not wholly immaterial ; it has atleast a speck of a reality.' Thus we waver on the brink of materiality and immateriality and can ascribe neither the one nor the other to the nature of the physical world. Thus the nature of the world according to modern physics also is unascertainable or inexpressible. The wave-picture proves that the exact nature of the physical universe can never be definitely known. The findings of modern physics thus vindicate the stand-point of Advaita Vedānta that the univere is neither wholly real nor wholly unreal,—that the universe of matter and radiation is simultaneously real and unreal, tangible and intangible, objective and subjective ; in other words, the universe is an appearance. Through different processes Vedānta and Physics arrive at the same conclusion.

Before concluding the paper we may refer to some noteworthy observations.

Long before Mayer and Joule, Vedānta knew and declared that the sum total of energy remained constant. Nothing can add to or take away from the sum total of the amount of energy which always remains constant though it may undergo various changes and modification of forms. In other words energy is conserved. According to Vedānta the diverse forms of matter and radiation spring from the One Cosmic Energy. Energy is the material cause of the world.

Neo-Physics has proved that matter and radiation are identical in substance. Old physics thought that matter and energy are wholly different entities but according to modern physics matter and energy are equivalent. Matter is energy and *vice versa*. Energy concealed is matter and matter released is energy. This truth was proclaimed more than a thousand years ago by Gauḍapāda, the grand preceptor of Śaṅkara, when he equated Śakti (energy) with Bhāva (matter) in his *Māṇḍūkyakārikā*.

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[12] *Physics and Philosophy*, p. 199.

The theory of *Pralaya* or cyclic dissolution of the world upheld by Vedānta and other Hindu scriptures is supported by the theory of entropy and law of thermodynamic equilibrium of modern physics. The law of eternal recurrence proclaimed in the *Ṛk Saṃhitā* and other scriptures of *Sanātana Dharma* that creation follows dissolution and *vice versa* in the self-same order is also corroborated by famous scientists like Eddington and Alexandar. Eddington observes in his *New Pathways in Science*: "The present course will repeat itself many times over an infinite number of times; in fact before it reaches the infinite, don't ask me whether I really believe or expect you to believe that this will happen. Logic is logic. That's all I say" (P. 62).

The sages of the *Upaniṣads* knew that there could be no creation without space. The *Chāndogya Upaniṣad* says: Ākāśo vai nāma-rūpayor nirvahitā (8.14.1) *i.e.*, it is space that makes possible the creation of names and forms. Today Einstein lends support to this fact when he says: 'Space is the pre-condition of creation.'

The above discussion proves beyond doubt that the findings of Modern Physics go to support the doctrine of Vedānta regarding consciousness and matter, the nature of the physical universe, nature of matter and energy, and law of eternal recurrence and dissolution.

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FUNDAMENTALS OF CYTO-GENETICS IN SANSKRIT LITERATURE

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INTRODUCTION

The term Cyto-genetics includes Cytology and Genetics. Cytology deals with the structure and function of cells, whereas Genetics is particularly the science of genes, the hereditary units that lie within cells. Cyto-genetics is a branch of Biology. In ancient India the subject of Cytogenetics was fully developed like Mathematics, Astronomy and Medicine.

According to modern Biology, up to this time, it is claimed that nearly 30 lacs of species have been searched out. In ancient India 80 lacs of species (Yoni) had been revealed. They were classed as : Sky-movers, **नभश्चर** 9 lacs; Water-movers, **जलचर** 10 lacs; insects and bacteria, **कृमि** 11 lacs; Botanical species, **स्थावर** 20 lacs; human species, **मनुष्य** 4 lacs and animals, **पशु** 30 lacs.

According to ancient Indian scholars, in human body there are 72 crore vessels supplying the protoplasm (Rasa).

हृदि ह्येष आत्मा । अत्रैतदेकशतँ नाडीनां तासां शतं शतमेकैकस्यां द्वासप्ततिर्द्वासप्ततिः प्रतिशाखा-नाडीसहस्राणि भवन्त्यासु व्यानश्चरति ॥ (प्रश्नोपनिषद् ३-६)

They proclaimed that the body is an aggregate of minute units, the cells (स्रोतस्) which are innumerable.

स्रोतसामेव समुदयं पुरुषम्.......... अतिबहुत्वात्खलु केचिद् अपरिसंख्येया-न्याचक्षते स्रोतांसि । (चरक, विमान, ५. ४.)

The next step was to find out the phenomena of its function. On this they said :

बिसानामिव सूक्ष्माणि दूरं विप्रसृतानि च ।
द्वाराणि स्रोतसां देहे रसो यैरुपचीयते ॥ (अष्टाङ्गसङ्ग्रह, शारीर, ६.१०७)

Jīva and Prāṇa

In general the terms Jīva and Prāṇa are used as synonyms. In a living organism Jīva and Prāṇa are so inter-related that one cannot be distinguished from another, and in the absence of the one the other cannot exist. The livingness is the joint effect of both Jīva and Prāṇa. The separate entity of Jīva and Prāṇa is recognised by those who know.

अङ्गिरसोऽङ्गानां हि रसः प्राणो वा अङ्गानां रसः (बृह० उ० १.३. १९)

Prāṇa is the bio-energy produced during the various processes of metabolism of food in the body. The food we take undergoes various chemical processes in the body and finally changes into protoplasm (रसः प्राणः), the living substance, which supplies the energy to the various functions of the body.

आपः पीतास्त्रेधा विधीयन्ते तासां यः स्थविष्ठो धातुः.... योऽणिष्ठः स प्राणः ॥
(छान्दोग्योपनिषद् ६.५. २)

The energy utilized in the body is obtained from the sun by the food material around us. So the sun is the ultimate source of energy.

आदित्य उदयन् यत्प्राचीं दिशं प्रविशति तेन प्राच्यान् प्राणान् रश्मिषु सन्निधत्ते । प्राणान् यद्दक्षिणां यत्प्रतीचीं यदुदीचीं, यदधो यदूर्ध्वं यदन्तरा दिशो यत्सर्वं प्रकाशयति तेन सर्वान् रश्मिषु सन्निधत्ते । प्राणाः प्रजानामुदयत्येष सूर्यः ॥ (प्रश्नोपनिषद् १.६.८)

Every *srotas* (cell) has protoplasm within itself and functions to maintain its individuality ; so it is a Prāṇa Kośa. Hence the number of Prāṇas is equal to the number of cells, प्राण-कोशs in the organism. A part of an organism may go under destruction in the absence of Prāṇas of that area, but not the whole organism.

अस्य यदेकां शाखां जीवो जहात्यथ सा शुष्यति, द्वितीयां जहात्यथ सा शुष्यति, तृतीयां जहात्यथ सा शुष्यति, सर्वं जहाति सर्वः शुष्यत्येवमेव खलु सोम्य विद्धीति होवाच ॥
(छान्दोग्योपनिषद् ६.११. २)

In the above quotation the word Jīva is used in the sense of Prāṇa.

It is now an established fact that Prāṇa is a product of food in the body and so it is subject to destruction, whereas Jīva is unproducible, hence immortal.

स्रोतसामेव समुदयं पुरुषमिच्छन्ति सर्वगतत्वात्सर्वसरत्वाच्च दोषप्रकोपनप्रशमनानाम् ।
(चरक, विमान, ५.४)

To the modern world Robert Hook was the first person, who in 1665, postulated the existence of some minute structural units forming the body of an organism. In 1839 Schwan and Schneider suggested that the unit of behaviour in a living organism was the cell, a proposition that has held good to the present day. The behaviour of different organisms and of different parts or organs is therefore, primarily determined by the peculiarities in structure and in the function of their individual cells. A similar idea was expressed long ago before 1839.

यावन्तः पुरुषे मूर्तिमन्तो भावविशेषास्तावन्त एवास्मिन् स्रोतसां प्रकारविशेषाः ॥
(चरक, विमान, ५.३.)

Ultimately in the end of the 19th century it was established that the body is an aggregate of various cells (स्रोतसां समुदयं पुरुषम्). This fact was mentioned by Maharṣi Caraka in the 5th century B.C. That proved to be true in the 19th century A.D. The verdict of Caraka was not a postulation but a scientifically proved traditional truth.

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The Origin of Cells

(स्रोतोद्भवः)

In 1859 Rudolf Virchove showed that all cells necessarily derive from pre-existing cells. In the very beginning there were unicellular organisms and later on multi-cellular organisms came into existence. It is evident that cells naturally came first into existence on this earth. According to modernists primitive cells were evolved into shallow water by chemical reactions. By and by protoplasm, membrane and nucleus were formed.

Long before the Christian era, Indian biologists were engaged in searching the truth of the formation of primitive cells. They said that the ocean was the place of creation (योनिः समुद्रः—जैमिनि) and so the first living substance, protoplasm, was formed in sea-water (आपो वा इदमग्रे महत् सलिलमासीदू एतास्ता आपः ।). After the formation of *Ap*, other constituents of cell came into existence and thus cell was formed.

आपो हि कललं भूत्वा यत् पिण्डस्थानुकं भवेत् ।
तदो व्यूहमानत्वाद् बीजमधिगच्छति ॥ वृक्षायुर्वेद

In the first process of creation plant cells were formed in nature. According to *Vṛkṣāyurveda* plant cells consist of *Ap* (protoplasm), *kalala* (membranous substance), *Piṇḍa*, (nucleus), and *vyūha* (gene and chromosomes). This structure is akin to that described by modern biologists.

The Animal Cells

या ओषधीः पूर्वा जाता देवेभ्यस्त्रियुगं पुरा । ऋग्वेद १०-९७-१.

According to *Ṛgveda*, animal cells were created 12 million years after the formation of plant cells. This period is near to that fixed by the scientists of today. During this period plant cells produced ample material for the production of animal cells. Here it should be remembered that animal cells also were produced in the seas.

सुभूः स्वयम्भूः प्रथमोऽन्तर्महत्यर्णवे । (वाजसनेयि-संहिता २३-६३)

In the beginning animal cells were not formed in driblets but in millions.

अण्डानां तु सहस्राणां सहस्राण्ययुतानि च ।
ईदृशानां तथा तत्र कोटिकोटिशतानि च ॥ विष्णु-पुराण २.७

The living material so formed was quite motionless. For the movement of animal organisms some stimulus was required, without which movement was not possible. This stimulus was supplied by the waves of the ocean.

त ऊर्मयः समारथन्नः फाइल फाइलिति तद्‌हिरण्याण्डं समैषत (जैमिनि)

आप (Protoplasm)—In Sanskrit literature the word *Āpas* is used generally in the sense of water. But in biological reference it is defined as protoplasm.

यत् प्रेषिता वरुणेनाच्छीभं समवल्गत ।
तदाप्नोदिन्द्रो वो यतीस्तस्मादापी अनु ष्ठन ॥
*   *   *   विभ्रत्याप इत् ताः ।
तीव्रो रसो मधु पृचामरंगम आ मा प्राणेन सह वर्चसा गमेत् ॥
इदं व आपो हृदयमयं वत्स ऋतावरीः ।
इहेत्थमेत शक्वरीर्यत्रेदं वेशयामि वः ॥ (अथर्व ३. १३. २-७)

In the above Mantras the formation of *Ap* is clearly described. Protoplasm comprises water (nearly 80 %), liquid (स्नेह), carbohydrate (मधु) in the form of glucose and phosphate, sulphate etc. This *Ap* is a living substance (आपो वै प्राण ।) *Ap* resides in cells (आपो हृदयम्). And all the living organisms comprise *Ap*, अप एव एतेभ्यः प्राणाः कामयन्ति ।

The word *Ap* is derived from the root *Apl* अप्लृ । The first constituent of Ap was water (आपो वा इदमग्रे सलिलमासीत्); in the first stage of origin Ap (water) was mixed with Indra (तदाप्नोदिन्द्रो वो यतीस्तस्मादापो अनुष्ठनः ।) The word Indra has been accepted in various meanings. One of them is Annam (इरम्+दः—यास्क). With the addition of this annam (इन्द्र) to water, a chemical change occurred and the living substance (protoplasm or Ap) was produced(प्राणः समैन्धन् तस्मादिन्द्रस्येन्द्रत्वम्—निरुक्त १०-८). The whole process from water to cell took place in the ocean (सुभूः स्वयम्भूः प्रथमोऽन्तर्महत्यर्णवे—यजुर्वेद)

Synonyms

In the European countries, from the very beginning, the words Sytos and Kitos have been used for cell The word Sytos appears to be a mispronounced form of the Sanskrit word *Srotas.* How Greek scientists used this word, is a matter of history. It is said that Sikander the Great, returning from India to his native land, had taken with him various Sanskrit books and a Pandit to translate those books. It is quite probable that the Greeks came in touch with many Sanskrit words.

Later on the word 'cell' was used by other scientists. This word may also be derived from the root Sru (स्रु) which means to ooze.

In Sanskrit literature many words have been used in different circumstances and contexts. They are as follows : पुरुष, प्राणकोश, हिरण्यगर्भ, हिरण्यकोश, अण्ड, कुमारकोश, स्वयम्भू , हृदय । These words have other meanings too.

Division of Cell

Cells are multiplied by their individual division. In general a single cell divides into two parts and then each part develops itself into a complete cell. There are two common ways by which all cells reproduce namely, mitosis and meiosis. It is not clear till now what factors perform this division.

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तेषां संयोगविभागे कारणं वायुः कर्म स्वभावश्च । **(चरक)**

Caraka says that cell-division is caused by Vāyu (ergastic substances), Karma and Svabhāva. Svabhāva as a cause of cell-division plays a great role in Ontogenic development, but Karma in Phylogenic development. Ergastic substances are the general causes of division which is an extrinsic factor but Karma and Svabhāva, the causative qualities of division, are transferred with the protoplasm of sex cell.

Changes in Cell (भावाः)

प्रियत्व-जनन-वर्धन-परिणाम-क्षय-नाशाः षड्भावाः ॥ (मुद्गलोपनिषद्)

From reproduction to the next division cell undergoes various changes. According to ancient biologists they are six,-reproduction, metabolism, growth, maturation, reduction and death.

Reproduction of cells (जनन)

Cells are reproduced by the process of division of individual cells.

Metabolism (प्रियत्व)

गुणा ये उक्ता द्रव्येषु शरीरेष्वपि ते तथा ।
स्थानवृद्धि-क्षयस्तस्माद्देहिनां द्रव्यहेतुकः ॥

The material forming the structure of body is derived from the food through various processes of Metabolism. The energy produced during these processes is utilized in the performance of different activities. Fundamental values are similar in both food and body tissues.

" Carbohydrates, fats, protein, vitamins, harmones etc. not only can be, but actually are burnt continuously in all cells all the times " (*Biology* by Weiz).

Growth वर्धन & *Maturation* परिणाम

After division, daughter-cells grow gradually into a complete cell. During this growth anabolism exceeds catabolism and cell increases its size. At this stage of metabolism internal parts of cell come to completion. After completion cell maintains itself for some time. This position of maturation continues till the process of division.

(*Reduction* & *Death*) क्षय तथा नाश

After maturation in cell, catabolism exceeds anabolism and so the cell is either reduced to death or is subjected to further division.

Kinds of Cells

यावन्तः पुरुषे मूर्तिमन्तो भावविशेषास्तावन्त एवास्मिन् स्रोतसां प्रकारविशेषाः ।
(चरक, विमान, ५. ३.)

Internally all the physiological functions are performed by the cells in the body. And so their categories may be numerous.

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स्वधातुसमवर्णानि वृत्तस्थूलान्यणूनि च ।
स्रोतांसि दीर्घाण्याकृत्या प्रतानसदृशानि च ॥ (अष्टाङ्गसङ्ग्रह, शारीर. २. ६. १०२)

According to shapes cells are columnar, ciliated, spherical, spindle-like, flat and long.

त्वङ्-मांस-शोणित-अस्थि-स्नायु-मज्जा षट् कोशाः ।

According to tissues, cells are of six kinds : skin [त्वक्], muscle [मांस], blood [शोणित], bone [अस्थि], fibrous [स्नायु] and marrow [मज्जा].

All these tissues form the structure of body. There is another type of cell which does not share in the formation of body but acts as a seed. It is called spermatozoa [वीर्य]. So the cells are somatic and reproductive.

Gene रेतस्

In literary Sanskrit the terms Śukra (शुक्र), Vīrya (वीर्य) and Retas (रेतस्) are used as synonyms. In scientific use, each has its own meaning. The word Śukra (शुक्र) is derived from the root Śuc (शुच् क्लेदे) which means a milky substance formed in seminal vesicles. Vīrya is different from the milky substance, it is a kind of cell (spermatozoa) which has vitality and movement. It is produced out of the epithelial cells. "Certain cells of the epithelium of the tubules are transformed successively into spermatogonia, spermatocytes, spermatids and spermatozoa." (West and Todd). The word Vīrya is derived from the root Vī (वी गति-व्याप्ति-प्रजननेषु), which means a substance which may move and has the power of reproduction (प्रजनन). The word Retas (रेतस्) has a different meaning from that of Śukra and Vīrya. Retas indicates a kind of particle residing in cell and also in spermatozoa.

In Sanskrit the word Retas has many synonyms. They are Hiraṇyam (रेतो वा हिरण्यम्, तैत्तिरीयब्राह्मण), Bījāmśa (यस्य यस्याङ्गावयवस्य बीजे बीजांशे वा-अष्टाङ्गसङ्ग्रह), Akṣaram (शुक्रस्य त्वाभ्यक्षरन् धारा ऋतस्य सादने-सामवेद १. ३४४).

During the process of cell-formation in ocean Retas was created in a long series of chemical re-actions which are described in various ways in Sanskrit literature.

प्रजापतिमेव रेतसा समर्धयति (तैत्तिरीय ब्रा. ३-९-७)
निरभिद्यत शिश्नाद् रेतो रेतस आपः (ऐतरेयोपनिषद्)

आपो ब्रुवन् ....फेनमसृजत...............मृदमसृजत ....
सिकताऽसृजत .... शर्करामसृजत .... शर्करामाऽश्मानं ....
हिरण्यम् । (शतपथब्राह्मण)

The modern cytologists did not succeed in giving such a vivid description of gene (रेतस्) in formation as is given in *Śatapatha Brāhmaṇa*. In the first stage Ap was formed from water. From Ap a long series of minute particles such as Phena, Mṛd,

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Sikata, Śarkarā, Aśman were formed. In the end from Aśman, Hiraṇya (हिरण्य) or Retas was formed.

Chromosome [व्यूह]

The word vyūha is formed from the root 'uh' with the prefix 'vi' (वि+उह वितर्के). In Sanskrit literature this word is used to express the sense of arrangement of things in a specific form. So it is used in the formation of military forces at the battle-field.

> उरः कक्षौ च पक्षौ च मध्यः पृष्ठं प्रतिग्रहः ॥
> कोटी च व्यूहशास्त्रज्ञैः सप्ताङ्गो व्यूह इष्यते। (कामन्दकीयनीतिसार २०-३५-३०)

The term vyūha (व्यूहं) is also used to denote the arrangement of genes (रेतस्) within the cell. This arrangement of genes is called chromosome. The number of chromosomes within a human cell is 24. A similar recognition was held by ancient Indian cytologists, as explained in the following quotation.

> प्रजायन्ते पशूनां प्रजात्या अपरिमित्य शर्करास्सिकता व्यूहेद्यं ……… …,सौम्या व्यूहति
> योनावेव रेतो दधाति व्यूहति तस्माद्योनौ गर्भा वर्धन्ते …… (काठकसंहिता २०.३.४)

A similar view is taken by *Taittirīya Samhitā* also :

> यं कामयेत पशुमान्त्स्यादिति परिमित्य तस्य शर्कराः
> सिकता व्यूहेत् परिगृहीत एवास्मै, समीचीनꣳ रेतः
> सिञ्चति पशुमानेव भवति, सौम्या व्यूहति सोमो
> वै रेतोधा एव तद्दधाति । (तैत्तिरीयसंहिता ५. २. ६.)

All the genes (रेतस्) arranged in 24 chromosomes, are consolidated in a cell. This consolidation is called Piṇḍa (nucleus). Besides the genes nucleus has protoplasm and membrane around it.

Sex-determination

> पितुः रेतोऽतिरिच्यात् पुरुषो भवति ।
> मातुः रेतोऽतिरिच्यात् स्त्रियो भवति ॥
> उभयोर्बीजतुल्यत्वान् नपुंसको भवति । (गर्भोपनिषद्)

The chromosomes (set of genes) producing sex-effects in a Zygot are called chromosomes and the others are called outosomes. To produce a particular sex the genic balance mathematically is necessary. If the number of x chromosomes equals the number of outosomes the female-producing genes outweigh and affect the genes-producing male and the individual is consequently female. If the female-producing genes are insufficient to accomplish this result, the individual is male.

Heredity

> तेषु मातृजानि मृदूनि त्वङ्मांस-मेदो-मज्जा-नाभि-हृदय-आमाशय-
> गर्भाशय-यकृत्-प्लीह-क्लोमास्य-गुदादीनि, पितृजानि स्थिराणि

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केशनखास्थिशुक्रसिरास्नाय्वादीनि (अष्टाङ्गसङ्ग्रह, शारीर० २)
पञ्चमात्सप्तमादूर्ध्वं मातृतः पितृतस्तथा (याज्ञवल्क्यस्मृति, आचार, ३.५३)

Some parental characteristics are transmitted to the immediate offspring, although the latter may appear after several generations. Maternal and paternal traits are transmitted by means of individual genes. Some characteristics in the offspring are produced anew.

According to ancient cytologists skin (त्वक्), muscles (मांस), fat (मेद), marrow (मज्जा), navel (नाभि), heart (हृदय), stomach (आमाशय), uterus (गर्भाशय), liver (यकृत्), spleen (प्लीह), lung (क्लोम), anus (गुद), and other soft organs are transmitted from mother to offspring, Similarly nails (नख), hair (केश), bones (अस्थि), semen (शुक्र), veins (सिरा), sinew (स्नायु) and other substances are transmitted from father to offspring. All these materials are transmitted in the form of gene (बीजांश). Along with these hereditary diseases and other traits also are transferred.

यस्य यस्याङ्गावयवस्य बीजे बीजांशे वा उपतप्तिर्भवति तस्य तस्याङ्गावयवस्य विकृतिरुपजायते । (अष्टाङ्गसङ्ग्रह, शारीरस्थान, २.५०)

पुरुषे ह वा अयमादितो गर्भो भवति ।
यदेतद्रेतस्तदेतत सर्वेभ्योऽङ्गेभ्यस्तेजः ॥

Eugenics

The propounders of this theory lay stress on the fact that the structure of the would-be offspring is constructed first in the male. And this is the first pregnancy.

Idiosynchracy

शुक्रशोणितसंयोगे यो भवेद् दोष उत्कटः ।
प्रकृतिर्जायते तेन * * * ॥ (अष्टाङ्गसङ्ग्रह)

Idiosynchracy is a particular tendency or nature of an individual which governs its whole structure and function. The modernist is not able to find out the real cause of the formation of this nature. In Sanskrit literature its description is found in detail.

Taxonomy and Evolution

Taxonomy is a branch of Biology which concerns mainly with the development of species. According to this theory a new species is formed with the genetical or chromosomal changes in a genus.

ऊनातिरिक्तौ मिथुनौ प्रजनयतः । ऊनमन्यस्य अतिरिक्तमन्यस्य ।
ऊनातिरिक्ताद् वै मिथुनात् प्रजाः पशवः प्रजायन्ते । —(जैमिनि बृ. २/६६)
जात्यन्तरपरिणामः प्रकृत्यापूरात्—(पातञ्जलयोगदर्शन ४. २)

ANCIENT INDIA'S KNOWLEDGE OF CHROMOSOMES

DR. P. V. VARTAK, POONA

In the field of Genetics we always think that the 20th century scientists are the first people to know chromosomes. But it is not quite true. The ancient Indian Ṛṣis knew about the chromosomes as well as Parthenogenesis.

We know that every sex cell in the human beings contains in its nucleus 24 chromosomes and these chromosomes control the character and functions of the individual. This concept is seen in the *Mahābhārata*.

Vyāsa has discussed the subject of Chromosomes and Genetics along with Metaphysics and Parapsychology in the Śānti Parvan. Up till now every worker on *Mahābhārata* has seen these facts through the glasses of Metaphysics. But it is not purely Metaphysics. It is a discussion of Metaphysics based on the facts of Physics and Physiology. We should differentiate these sciences so that pure Physiology and Genetics will be revealed to us.

In Adhyāya 302 of Śānti Parvan, Vyāsa has mentioned the thoughts of Vasiṣṭha on the origin of Universe. In these thoughts Vasiṣṭha has based his discussion on this problem about the origin of a person or an embryo. In this discussion Vasiṣṭha says :

"There is a group of 24 principles in all the living bodies. Every body is composed of Piṇḍas containing 24 principles. Such bodies containing 24 principles are present on the earth or in the water or in the skies. It may be a man or a cow or any other creature; it contains 24 principles. All these bodies containing 24 principles are perishable.

"Beyond these 24 principles is a thing known as 'Viṣṇu'. Actually this is not a principle, but it supports these 24 principles and hence is also taken as the 25th principle, by some experts in this science. This visible body is composed of invisible bodies containing 24 principles. The 25th principle is, in fact, quite distinct from the 24 principles, but as it is locked up with them, it thinks itself as one of them. In fact, it is only Energy".

If we consider this description it will be clear that these 24 principles are our 24 chromosomes, the 25th is the Nucleus and the invisible bodies or Piṇḍas forming our visible body are the microscopic cells of the body. Vasiṣṭha has given examples of Man and Cow. Our Genetics also has proved that man as well as ox possess 24 chromosomes. In the list of examples Vasiṣṭha includes mosquito, insects, mouse, deer, horse, elephant, donkey, tiger, trees and organisms present in the dirt.

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Further Vasiṣṭha says : "Due to this body,—i.e., the one containing 24 principles, one has to suffer from mental diseases, opthalmic and dental diseases, migraine, Ascites, Diabetes and Diabetes incipidous, Leukoderma, Asthma and Epilepsy. All of us know that all these diseases mentioned by Vasiṣṭha are hereditary and modern scientists have proved that these are transmitted by genes.

We are yet unable to decide the functions of all the 24 chromosomes, but Vasiṣṭha has labelled the 24 as follows:

	3	Basic-Rājasa, Tāmasa, Sāttvika
	5	Basic-Physical, Ākāśa, Tejas, Vāyu, Jala, Pṛthvī.
	5	Dependent on above-voice, feel, appearance, smell and secretions
	5	Sense organs-ear, skin, eyes, tongue and nose
	5	Capacities-speech, upper extremities, lower extremities, Alimentary system and Genetourinary system
	1	Intelligence
TOTAL ..	24	

Probably this classification of chromosomes may prove to be correct.

On getting this knowledge from Vasiṣṭha, King Janaka asks him some questions in which he shows possession of the following knowledge (Adhyāya 305, Śānti Parvan):

A female cannot be fertilised without a male and male also cannot reproduce without the help of a female. Every offspring contains some characteristics of father and some, of mother. It was also said that the child derives his bones, muscles and nervous system from father and skin, fat, blood etc. from mother.

Even today we cannot tell which part of the foetus is derived from ovum and which part from the sperm. But the ancient sages tried to find an answer to this. Of course, this belief was not taken to be correct by other thinkers like Vasiṣṭha. Vasiṣṭha says that according to some Sāṅkhyavādins, the foetal body formed only from the ovum (by the mother); the father has nothing to do with that formation.

This view taken by the ancient Sāṅkhyavādins is quite correct. The scientists of the 20th century A.D. have accepted this fact as true and this is called Parthenogenesis. In this phenomenon of Parthenogenesis, an embryo is formed without fertilisation of an ovum by a sperm. By mechanical truama, like a needle puncture, the female pronucleus starts dividing and gives rise to an embryo, each cell of which contains only haploid number of chromosomes. In other cases of Parthenogenesics, only one Polar body is extruded, or the second Polar body joins again with the female pronucleus. In these cases, the ovum contains a nucleus with diploid number of chromosomes. In mammals this phenomenon is not easy to

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demonstrate, but still it can occur *e.g.*, in rabbits by means of ultra-violet rays or by cooling.

On this basis of modern knowledge, we can say that the statement of Vasiṣṭha that embryo can be developed only by the female is fully correct. Naturally what Vyāsa has recorded in his *Mahābhārata* is also quite true.

Later on Vasiṣṭha says that the opposite is also true. The whole of the body of the foetus can be developed from semen only. Vasiṣṭha speaks of this phenomenon confidently because he himself was born, with Agastya, in the same curious fashion, in a pitcher, from the semen of Mitrā-Varuṇa. In support of this Vyāsa cites the example of Droṇācārya, who was born without any mother from the semen of Bhāradvāja. Ṛṣi Bhāradvāja took his own semen in a container, Droṇa, from which a male child was formed. Hence the child was named Droṇa. This Droṇa should not be thought of as ordinary Droṇa with which we drink. It mut have been something else.

Similarly, the twins Kṛpa and Kṛpī, were developed in a container by processing the semen of Gautama, without the help of a woman. Modern genetics admits that it is the sperm which has got x and y chromosomes denoting female and male respectively, while the ovum has both x chormosomes. Hence by Parthenogenesis, the ovum will produce both the females while the sperm will reproduce one male and one female. So this miracle as recorded in *Mahābhārata* is consistent with the modern genetics.

In adhyāya 308, Vasiṣṭha says: "There are three things, Buddha, Abuddha and Guṇavidhi. The Prakṛti, with 24 principles is called Guṇavidhi. These 24 principles do not know the 25th, which is called Jīva. But the Jīva knows the 24 principles. Even though the Jīva controls the 24 principles it is not the whole and sole authority. The 25th itself is governed by the 26th, which is nothing but energy. The 26th knows and controls the 24 principles as well as the 25th Jīva, so it is called Buddha. As Jīva does not understand this Buddha, it is called Abuddha.

This description can be correlated with modern knowledge. Prakṛti with 24 Guṇavidhi is our cell with 24 chromosomes. Jīva is our nucleus and the Energy controlling the nucleus is Buddha, which we do not know as yet. Even though we do not know this energy, we have to accept that there is some power which controls the activities of the nucleus. This supreme power is Buddha or Paramātman.

Vasiṣṭha further adds one very important point. He says: "Practical knowledge of these can be secured by an individual who has microscopic vision" (Sūkṣmadarśin).

From this statement we can infer that there must have been some device, like an electron microscope, to see such microscopic things. It may be a material device like microscope or an immaterial device based on Yogic powers. As Vasiṣṭha has described so perfectly all the things which modern science has proved, it can be inferred that he must have seen all these bodies by some device. In support of this inference, there is one more reference of microscopic life or organisms in Adhyāya 15. It is probably on this knowledge of microscopic organisms that Suśruta was boiling his instruments before surgery.

The name Guṇavidhi given to these 24 principles is quite meaningful as it denotes Character and Functions, both of which are controlled by these principles. We call these chromosomes, but the name chromosome is not so meaningful as Guṇavidhi.

Probably it is on the basis of this knowledge of genetics that in the yajña the Ṛṣi experimented and developed the two human bodies artificially, namely, Dhṛṣṭadyumna and Draupadī. For this "great experiment" as mentioned by Vyāsa in Ādiparva, Adhyāya 167, King Drupada spent wealth equal to 10 crores and 80 thousands of cows. From the very cost we may assume that this was not an ordinary Yajña, but a great and unique experiment.

Similarly, Vyāsa himself did an experiment on the fertilised ovum of Gāndhārī, which she had aborted deliberately. Vyāsa put this aborted mass of cells into a kumbha, a special container having some nutrient medium, "Ghṛta". He then divided this mass of cells into 101 parts and kept these separately, one part in each of the 101 kumbhas. Then these kumbhas were kept in a secret place well protected. After some period 100 sons and one daughter were formed. This kumbha should not be taken as an ordinary clay pot. Elsewhere the word kumbha is used to denote "Wet Cell", with the help of which Agastya performed electroplating and water-analysis. Agastya used this technique to prepare hydrogen for his aeroplane. This electricity was called as Mitrā-Varuṇa Tejas by Agastya. Vasiṣṭha was also conversant with this electricity. As Agastya's kumbha has got a special meaning, so also Vyāsa's kumbha has got a special meaning.

To-day we use the word 'test tube' on many occasions. Is it the same test tube which we use to detect urine sugar, that is used in the experiments on living cells? No, not at all. Even though we speak of 'test-tube embryo' it is not an ordinary test tube. Similarly, this kumbha was not an ordinary kumbha, but a highly specialised kumbha.

Thus from the description in the *Mahābhārata*, we can infer that those ancient sages had knowledge of chromosomes and genetics and they were experimenting in that field quite successfully. One may question about the possibility of such an advanced knowledge in olden days but we must remember that Suśruta performed Plastic Surgery in those days and his methods were much better than those of modern surgeons who have accepted his techniques *e.g.*, the use of forehead skin flap for facial. The ability of Suśruta was not recognised a few years ago by modern surgeons, but now everybody accepts it. The same thing

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may happen in the field of Genetics too. After further investigations this ancient knowledge may become acceptable to modern science. The *Mahābhārata* is not a book on Genetics, so details about this science are not given in it. If we can find an ancient book on Genetics by sages like Vasiṣṭha, we may find details of their work in this field. Vyāsa himself may have written details about his own experiment on Gāndhārī's embryo, but unfortunately it is not available. He had written 60 lacs of ślokas but probably only one lac are available now. In the remaining 59 lacs of ślokas was perhaps included all the knowledge of other sciences; Genetics might have been included there. In fact *Mahābhārata* is an Encyclopaedia.

The idea behind this paper is to bring the vast ocean of knowledge and scientific advances of our ancient sages into light. This may work as a stimulus to future Indian generations to see into the past and develop our future, in our own, without the aid of foreign countries. We must stand on our own feet in the scientific world. We must add something new to the knowledge of the world. We should try to take the lead of the world as our ancient rishis did.

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TECHNICAL HERITAGE OF ANCIENT, EARLY AND MEDIEVAL INDIA

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Vedic Foundations — Upa-Vedas, the Founders of Technical Sciences

Brajendra Nath Seal took a lead in writing a monograph 'The Positive Sciences of the Ancient Hindus', but his investigations, as he himself says, relate to the post-Vedic period 500 B.C. to 500 A.D.

If there were Vedas representing ritual, religion and philosophy, there were also Upa-vedas, on the material sciences, technical and positive. Hindus had founded both the Vidyās, the Parā and the Aparā. Every Veda has an Upaveda. Āyurveda, the science of medicine (including Chemistry, Botany and Physiology) was attached to *Ṛgveda.* Similarly, Dhanurveda, the Military Science, was attached to *Yajurveda,* Gāndharva-Veda and Sthāpatya-*cum*-Artha-Veda to *Sāma* and *Atharva* Vedas respectively. This Artha-Upaveda represents Social organisation and State-craft. We know of the *Arthaśāstra* of Kauṭalya, the most reputed treatise on polity and war-strategy. Thus our Vedas and Upa-vedas have made our life perfect in both the aspects, the spiritual and the material. Otherwise how could we have evolved the definition of Dharma as : "यतोऽभ्युदयनिःश्रेयससिद्धिः स धर्मः".

Dharma does not mean only dogma or ritual ; it means also the sustaining factors of life in its most complete aspect. Abhyudaya stands for material prosperity and Niśśreyasa for Mokṣa, the release of the soul from bondage. These are cardinal postulates which have perfected our culture. Thus we can appreciate the balancing of Materialism and Spiritualism in our culture.

Āyurveda : The two Upavedas, namely, Āyurveda and Sthāpatyaveda being very intimately related to the very existence and living of man, were naturally very popular and their culture, studies, systematisation and propagation found appropriate codification in later literature. The founders of these two sciences belong to a hoary past, as ancient as Vedic times. Though much has been written on Āyurveda, its study on profounder scientific foundations needs revival so that the contribution of India to positive sciences like Chemistry, Physics, Physiology and Botany may come into it own. The health ideals of the nation need to be based on the indigenous ideals of living, culture and civilization.

Hindu achievements in the field of Medicine and Surgery, Chemistry and Mathematics have been well known. Hindu contributions in the field of Botany, Zoology and Veterinary Sciences have to be taken up. Botanical and Zoological data are found in a the *Mānasollāsa* or *Abhilaṣitārtha-cintāmaṇi* of the later Chalukyan king Somesvara III. Similarly the treatment of Veterinary sciences in this and other treatises like *Śukranīti, Śālihotra, Aśvaśāstra, Vāji-praśamsā, Harihara-caturaṅga,* Nakula's *Aśva-śāstra,* Jayadatta's *Aśva-Vaidyaka, Sāra-sindhu* referred to by Nakula etc. along with *Mātaṅgalīlā, Hastyāyurveda, Gaja-cikitsā* and several others fully corroborate this technical heritage of ancient India. Classifications — botanical, medical and dietatic ; morphology ; physiology (stems, roots, flowers, leaves, plants), heredity, ecology of plants, plant-pathology and breeding etc. were well known to our ancient scientists. Further, India being an agricultural country, could not have afforded to neglect the veterinary sciences.

Sthāpatya-Veda : This Upaveda, gave rise to two technical sciences, *Vāstuśāstra* and *Śilpaśāstra*, the science of Architecture including Engineering and Town-planning and Iconography and Sculpture, Painting and other allied arts. The text-books of Vāstuśāstra are records of oral tradition which go back to an undefined past. The testimony of the *Bṛhatsamhitā* of the 6th century A.D. in this context also supports this antiquity. Varāhamihira himself proclaims the authority of earlier Ācāryas like Garga and Manu on this lore. The *Matsyapurāṇa* enumerates the eighteen preceptors of Vāstuśāstra :

भृगुरत्रिर्वशिष्ठश्च बिश्वकर्मा मयस्तथा ।
नारदो नग्नजिच्चैव विशालाक्षः पुरन्दरः ॥
ब्रह्मा कुमारो नन्दीशः शौनको गर्ग एव च ।
वासुदेवोऽनिरुद्धश्च तथा शुक्रबृहस्पती ॥
अष्टादशैते विख्याताः शिल्पशास्त्रोपदेशकाः ॥

and many of these were Vedic Ṛṣis. Hence the Vedic foundations of Vāstuśāstra cannot be said to be over-estimated. The conception of *Vāstu*, its *Maṇḍala* and its presiding lord *Puruṣa* are as ancient as Vedic times. The very Mantra of *Vāstupuruṣa* is based on the analogy of the Vedic Vāstoṣpati. The foundations of the building-construction, whether an altar or a shed of initiation or of scacrifice, a residential house or the abode of deity, all go back to the Sūtra period.

The word 'Śilpa', though comparatively later than 'Vāstu' so far its meaning of ornamentation and varied motifs is concerned, is also as old as the Vedas. The *Aitareya Brāhmaṇa* VI.5.27 is a valuable testimony on this subject, 'Śilpāni' or works of art : they are defined as imitation of divine forms ; by employing their rhythms, a material reconstitution is effected of the limited human personality. Similarly the *Śulba-Sūtras* show a clear development in the science of Architecture, the *Sthāpatya Veda*. The *Śrauta Sūtras* which belong to 2000–1500 B.C. contain the rules for rites ordained by the Veda. Each *Śrauta Sūtra* seems to have had its own *Śulba-Sūtra* or section dealing with the measurements or the 'geometry' of the altar. The Vedi is the sacred ground measured out for the Yajña and this Vedi is the mother of Hindu Temple. Science, philosophy, ritual, religion and metaphysics have each contributed to evolve a meeting of Macrocosm and Microcosm in Prāsāda, the Hindu Temple. Prāsāda is thus designated as Prāsāda-puruṣa, the body corporate. This *Sthāpatya Veda* led to the growth of a vast literature on architecture in the *Purāṇas*, *Āgamas*, *Tantras*, *Pratiṣṭhāpaddhatis* and the *Vāstu/Śilpa* texts proper, embodying later developments.

Artha-Veda : This Upa-Veda gave rise to all the later literature dealing with social organisation, polity and war. The *Arthaśāstra* dominated all thinkers of ancient India. It deals with the totality of social, political and economic relationship and shows how they are to be properly organised and integrated with one another. All relationships, says Uśanas, is rooted in the Daṇḍanīti (*Mahābhārata* XII.62 28-9). Manu goes to the extent of declaring that it is Daṇḍa who is the real king, the real leader and the real protector : "धर्मं दण्डं विदुर्बुधाः"

The rules about the functions and duties of the king and the welfare of the state were therefore naturally called *Daṇḍanīti*. According to Parāśara, wealth is the root of virtue (*Dharma*) and pleasure (*Kāma*). There were several predecessors of Kauṭalya like Bhāradvāja and Vātavyādhi whom Kauṭalya quotes.

Gāndharva-Veda : The science of Music is equally old and there are abundant references to its antiquity in the later literature on Music, and its related subject of Dance. The Science of Music is intimately related with Metaphysics. Nāda and the concept of Nāda-Brahman and Śabda-Brahman are well known. The ancient music is conceived of sound in pure form or Brahman, in addition to it being conceived as a means of aesthetic enjoyment. The *Ārcika*, *Gāthika* and *Sāmika* recitals of the Vedic period based on one, two and three notes evolved into the full music of seven notes. This led to the growth of secular music. Then followed the Epics, Purāṇas and a large number of ancient texts and authors like Bharata, Nandi, Kohala Dattila, and Mataṅga who were the first promulgators. Later a large literature grew in the field of music and dance.

The texts deal with Svaras, Rāgas, Tālas, Instruments and Compositions. The Indian music instruments form a rich variety, whose history can be traced from the Vedic times. In each of the four classes, String, Wind-blown, Percussion and Cymbals, a large variety was known from texts and practice.

Characteristics of the Technical Sciences and the Fine Arts of India

The most important characteristic of our technical sciences, especially Architecture, is the philosophical background, the philosophy of *Vāstu-Brahman*, a detailed treatment of which may be seen in my volume entitled 'Śilpaśāstra', 'Philosophy of Vāstu-Brahma and its impact on Temple Architecture'. We shall devote some attention to the aesthetic ideals of our Fine Arts. The *Viṣṇudharmottara* has remarkable contribution on this subject and king Bhoja's *Samarāṅgaṇasūtradhāra*, has also noteworthy contribution.

Iconography is both a science and an art. The artistic perfection of an image has to be accomplished in such a way as to arouse in us the aesthetic experience akin to what we get from poetry and music. According to the Indian aestheticians, the main purpose of poetry is to rouse pleasure, 'Āsvāda' or 'Rasāsvāda'. This Rasāsvāda is extolled as 'Brahmānanda-sahodara'. It is because of this fundamental stand-point that we do not have tragedies in our dramatic literature. The Hindu view of life is one of unbounded faith in eternity, a profound sense of optimism and a sublime outlook of life, coloured by the noumenal existence and heavenly bliss,

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both *Apavarga* and *Svarga*. Naturally, therefore, all arts, be it poetry, music, painting, or dance, are to be viewed from this lofty idealism. In all the phases of Indian art, this *Rasa* has played a very prominent role. The Indian belief is that the Supreme Being is *Rasa-svarūpa*. (रसो वै सः).

Image-worship for which icons were to be made of manifold materials, with manifold symbols, worthy of desired end, has to be done in a manner of accomplished art. In dance and drama there is an identification of the spectator with the *Naṭa*, the actor. A similar identification is essential between the worshipper and the worshipped. This is possible only through the rousing of *Rasa* in art. The sculptural monuments corroborate this. This aim of art becomes instrumental in producing the *Bhāvavyakti* and this is dependent on the *Rasas* and the eyes (*Dṛṣṭis*) which are the means of expressing *Rasas*.

रसानामथ वक्ष्यामो दृष्टीनामिह लक्षणम् ।
तदायत्ता यतश्चित्रे भावव्यक्तिः प्रजायते ॥

Samarāṅgaṇasūtradhāra

Here *Citra* stands both for the pictorial images as well as the sculptural ones. Hence according to the *Samarāṅgaṇa* it is the supreme achievement of the image-maker to see to this 'bhāva-vyakti'. This aesthetic ideal is the major contribution of Indian canons of art as propounded in the texts like the *Viṣṇudharmottara* and the *Samarāṅgaṇasūtradhāra*. This gives a distinct and unique character to the Fine Arts in India. The oft-quoted aphorism 'ब्रह्मानन्दसहोदरो रसः' is not without significance and high meaning. It pre-supposes the ideal of the 'Beautiful' (*Sundara*) in its real perspective. The beautiful is not only to be viewed in anatomical perspective, but also in the inner manifestation. It pre-supposes the truthful, the '*Satya*', both internally and externally and the art which is both *Satya* and *Sundara*, that alone becomes the beneficient, the '*Śiva*'. It is the realisation of this 'God' in His three aspects that the Indian seers always aimed at.

Thus a perusal of the sections on painting in the *Viṣṇudharmottara* and Bhoja's *Samarāṅgaṇa-sūtradhāra* will show how *Citra* is based on Nāṭya. The poses, the hands of dance called *Nṛtyahastas* and the *Rasadṛṣṭis* are studied elaborately in Nāṭya and this study is absolutely necessary for and is fully utilized in painting and sculpture. What the hand-poses express (the Varada, Vyākhyāna, Jñāna, Yoga and other Mudrās), the *Rasa-dṛṣṭis* make more explicit.

Symbolism in Indian Art : I have maintained the thesis that *Mudrās* should not be taken only to denote the poses of hands, body and legs and feet but they are also the symbolic representations of the characteristic emblems of the divinities. In this sense all the symbols characteristic of a particular deity stand for *Mudrās*.

एकोनविंशतिर्मुद्राः विष्णोरुक्ता मनीषिभिः ।
शङ्खचक्रगदापद्मवेणुश्रीवत्सकौस्तुभाः ॥

......................शिवस्य दश मुद्रिकाः ।
लिङ्गयोनित्रिशूलाख्याः मालेष्टाभीमृगाह्वयाः ॥
सूर्यस्येकैव पद्माख्या सप्त मुद्रा गणेशितुः ।
लक्ष्मीमुद्रार्चने लक्ष्म्या वाग्वादिन्याश्च पूजने ॥
अक्षमाला तथा वीणा व्याख्या-पुस्तक-मुद्रिकाः ।
सप्तजिह्वाह्वया मुद्रा विज्ञेया वह्निपूजने ॥

Ninteen Mudrās are known for Viṣṇu, like *Śaṅkha*, *Cakra*, *Gadā*, *Padmo*, *Śrīvatsa Kaustubha* and *Vanamālā*. Śiva has ten Mudrās sacred to him *i.e.*, the *Liṅga*, the *Trident*, the *Rosary*, *Ḍamaru* etc., the Sun has only one Mudrā, the *lotus*. Gaṇeśa has seven Mudrās like the Tusk and the Goad. The Mudrās for Sarasvatī are the *Lute*, the *Book* and the *Rosary*. The Mudrās of Agni are the seven flames.

The symbols or Mudrās are the conductors, so to say, between the image and the idea. Thus the elephant in the image of Indra, brings the whole idea of Royalty in which an elephant is a fundamental emblem. The bull, in India, is a symbol of *Dharma* and was thus used as the Vehicle of Śiva. Thus symbolism is the key-note of Indian art.

Contribution that our Technical heritage can make in present-day national reconstruction

Sanskrit language, literature and civilization form the real bed-rock on which our National Integration is founded. Sanskrit in the past was a full-fledged study where different branches included Medicine, Town-planning, Arts, Astronomy, Military Science, Polity, Strategy of War and State-craft, besides Literature and Philosophy. Modern India needs planning which would bring about national integration based on its cultural heritage. We always look to the West and imitate their patterns. There is a rich literature in Sanskrit on branches of study and researches on these can certainly unfold fascinating ideas and practical methods of work in all these spheres. Taking only one branch, ancient Hindu architecture, including civil engineering, treatises like the *Mānasāra*, *Mayamata*, *Śilparatna*, *Samarāṅgaṇasūtradhāra* and *Aparājitapṛcchā* and the remarkable archaelogical remains in the realm of town-planning and architecture, can afford ideas worthy of incorporation in our present-day planning and construction.

The Indus Valley civilisation and Harappa culture show the beginning of advanced technique of town-planning. The Vedic village was an ideal habitation. Who contributed all this? It is the Sthapatis, the ancient architects, together with the patrons of the art and architecture, the ruling dynasties, in the different parts of the country who could devotedly and dedicatedly surrender all their wealth in the establishments of huge temples through the length and breadth of this vast sub-continent. Temples like Liṅgarāja at Bhuvaneśvara, the Sun Temple at Konark, Kandariya Mahādeva at Khajuraho, Bṛhadīśvara at Tanjore, Mīnākṣī-Sundareśvara at Madura and Rāmanātha at Rāmeśvaram and the famous ones at Māmallapuram, Kāñchipuram, Cidambaram, Aihole, Badami, Pattadakal, Udaipur, Modhera, and Mount Abu bear testimony to this great artistic development. This could not have been possible if we did not have a systematised body of knowledge of art and architecture and the learned, trained devoted architects. We are not going to revive our Temple-building in the modern age ; but we need to found new town-ships, and build residential houses, factories, laboratories, offices, bridges, dams and the like. In these building-developments are we not going to re-orient our architectural policy on the fundamentals of ancient Indian architecture ? If we could do this, we can have a national character; otherwise we merge in the great ocean of imitation. This can be done by the study of the Sanskrit treatises on art and architecture. A Western engineer or architect is familiar with the treatise of Vitruvius but our Indian architects are quite ignorant of even names of *Mānasāra*, *Mayamata*, *Samarāṅgaṇa* and *Viśvakarmā*. We have founded so many colleges of architecture. Is there any place for these treatises in their curriculum ?

Sthapati and Sthāpatya-the role of an architect: In our tradition *Sthāpatya* is fourfold from the standpoint of equipment and it is eightfold from the standpoint of art. According to the *Samarāṅgaṇasūtradhāra* an architect must possess the fourfold equipment of *Śāstra* (knowledge of the Science and its allied sciences like Mathematics), *Karma*, the skill and craftmanship, *Prajñā*, the initiative and the genius of mind and intellect which must help him at the time of the operation, and *Śīla*, a character above reproach. This last qualification is very important in the present-day national reconstruction. The following quotation will be interesting to help us realise the importance of Sanskrit lore even in the education of modern Engineers and Architects :—

यस्तु शास्त्रमविज्ञाय प्रयोक्ता स्थपतिर्भवेत् ।
हन्तव्यः सं स्वयं राज्ञा मृत्युवद् राजहिंसकः ॥
यस्तु केवलशास्त्रज्ञः कर्मस्वपरिनिष्ठितः ।
स मुह्यति क्रियाकाले दृष्ट्वा भीरुरिवाहवम् ॥
केवलं कर्म यो वेत्ति शास्त्रार्थं नाधिगच्छति ।
सोऽचक्षुरिव नीयेत विवशोऽन्येन वर्त्मसु ॥
शास्त्रकर्मसमर्थोऽपि स्थपतिः प्रज्ञया विना ।
फलेयु कर्मभिरन्याभिः (?) स्यान्निर्मद इव द्विपः ॥
प्रत्युत्पन्नमतिर्यः स्याद् वाहकः स्थपतिस्तथा ।
कर्मकाले न मुह्येत स प्रज्ञानेनोपबृंहितः ॥
अप्रज्ञेयं दुरालोकं गूढार्थं बहुविस्तरम् ।
प्रज्ञापोतं समारुह्य प्राज्ञो वास्तुनिधिं तरेत् ॥
ज्ञानवांश्च तथा वाग्मी कर्मण्यपि च निष्ठितः ।
एवं युक्तोऽपि न श्रेयान् यदि शीलविवर्जितः ॥
रोषाद् द्वेषात् तथा लोभान्मोहाद् रागात् तथैव च ।
अनन्यचिन्त्यत्वमायाति दुःशीलानामविक्षयात् (?) ॥

शीलवान् सर्वकर्माहः शीलवान् प्रियदर्शनः ॥
शीलाधाने परं यत्नमातिष्ठेत् स्थपतिः सदा ।
ततः कर्माणि सिध्यन्ति जनयन्ति शुभानि च ॥

This is the fourfold Sthāpatya. As regards *Aṣṭāṅga Sthāpatya*, the following from the *Samarāṅgaṇasūtradhāra* in worth quoting:

प्रोक्तं चतुर्धा स्थापत्यं वास्तुतत्त्वस्य सिद्धये ।
ब्रूमस्तदेव चेदानीमङ्गैः संयुक्तमष्टभिः ॥
तेष्वङ्गं प्रथमं प्रोक्तं वास्तुपुंसो विकल्पना ।
पुरस्य विनिवेशस्तु द्वितीयं द्वारकर्म च ॥
रथ्याविभागः प्राकारनिवेशोऽट्टालकस्य च ।
विनिवेशः प्रतोलीनां विभागास्थानकानि च ॥
प्रासादश्च तृतीयं स्याच्चतुर्थं च ध्वजोच्छ्रितिः ।
पञ्चमं नृपतेर्वेश्म स्थानान्तरविभक्ति च ॥
चातुर्वर्ण्यविभागश्च गृहभागश्च षष्ठकम् ।
सप्तमं यजमानस्य शालायां मानमीरितम् ॥
यज्ञवेदीप्रमाणं च कोटिहोमविधिस्तथा ।
अष्टमं राजशिबिरनिवेशो दुर्गकर्म च ॥
यो वेत्त्यङ्गान्यमून्यष्टौ सोऽत्र स्थपतिसत्तमः ।
यशो मानं स लभते पूज्यते च नराधिपैः ॥
अशास्त्रज्ञमकर्मज्ञं स्थपतिं यः प्रयोजयेत् ।
न तस्य वास्तु सिद्ध्येत सिद्धमप्यसुखावहम् ॥
तस्मात् कर्म च शास्त्रं च यो वेत्ति द्वितयं नरः ।
अष्टाङ्गमपि यो वेत्ति स राज्ञः स्थपतिर्भवेत् ॥

Genesis and Genius of a residential house : Our *Purāṇas* and *Āgamas* proclaim: **शिलास्तम्भं शिलाकुडयं नरावासे न योजयेत् ।** What is its implication? Our climate is hot for the major part of the year. Can we afford to live in a hot house ? Shall this heat not tell upon our health, longevity and stature? Were our fore-fathers fools or half-civilized to live in thatched houses or Śālā-houses (wooden-*cum*-mud structures) to ward off the heat of the sun? While they could build soaring edifices for gods and goddesses, they preferred the mud houses for their own living.

Code of Masonry, the building Bye-laws and House-Plans

The twenty good qualities of masonry **विंशतिश्चयगुणाः** and the procedure in laying the bricks, *Caya-vidhi* with the aid of the eightfold measure, *sūtrāṣṭakam*, provide insights into the technique of civil architecture in ancient India. Other

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details have been studied and brought out in my work *Vāstuśāstra* Vol. I — ***Hindu Science of Architecture*** with special reference to Bhoja's *Samarāṅgaṇasūtradhāra.*

Fundamental Canons : We know that the central post was the prime regulator of house-construction in India. It was as fundamental as the trunk of a tree. Tree-model was the primordial model of a house-plan (*Cf.* the story of the birth of human home-the Śālā-house as related in *Purāṇas* and the *S.S.*) and the abundant application of pillars was one of the chief features of an Indian building, whether a residential house or a palace, or a *Sabhā* or a temple or a temple-pavilion. Naturally we cannot say which pillars are more basic than the others. But if we ponder over the problem and visualise the basic importance of the structure, we must come to the conclusion that as many as five pillars are cardinal. These are the four cardinal and one central posts. Similarly, sustaining the analogy, there are the following five fundamental pillars of the stable edifice of our Science and we can call them the fundamental canons :

1. *Diṅnirṇaya,* Doctrine or Orientation. 2. *Vāstu-pada-vinyāsa,* the Site-planning. 3. *Māna* (Hasta-lakṣaṇa), the proportionate measurements of a structure. 4. *Āyādi-ṣaḍvarga,* the six canons of Hindu architecture. 5. *Patākādi-ṣaṭ-chanda,* the character of the building (its aspects and prospects).

Vāstupada-vinyāsas have been in practice since the Vedic times. Now it is no more than a ritual. We do call a priest and an astrologer when we start a building but do we understand the scientific and technical implications of this fundamental canon as adumbrated above like *Diṅnirṇaya* or *Prācīsādhana ? Vāstupada-vinyāsa* is a site-plan in the language of the modern architecture. This includes allotment of the padas to the deities. The central square is always reserved for Brahmā. He is the lord of creation. The north-east corner of the chart starts with Īśāna which corresponds to the ultra-violet segment of the solar spectrum and it has a variety of attributes which need to be studied properly. Similarly the south-east corner of the chart represents Agni. It corresponds to the infra-red segment of the solar spectrum. All these deities really stand for the rays of the sun to be regulated in such a scientific manner as to ensure eastern frontage. This is the sum and substance of the doctrine of orientation, the most important canon of our ancient civil architecture.

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SCIENTIFIC WORKS IN SANSKRIT TRANSLATED INTO FOREIGN LANGUAGES AND VICE VERSA IN THE 18th & 19th CENTURIES A.D.

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From pre-historic times as also from early historic periods, India, due largely to her peculiar geographical position, has been maintaining active cultural relations with her neighbouring as well as far-flung countries. It is not therefore surprising that she has been destined to play from a very early date an important role in the transmission and diffusion of scientific ideas. In the sixth century B.C., the Achaemenian Empire and the Greco-Bactrian Kingdom provided an effective bridge between India and the Mediterranean world[1,2]. A little before or about the beginning of the Christian era, thriving commercial relations were established between India and Ptolemaic Egypt and Rome's Eastern Empire. Instances of transmission of Indian medical prescriptions and theories have been noticed in the Hippocratic collections, Plato's *Timaeus*, and in the writings of Roman physicians and encyclopaedists such as Celsus, Scribonius Largus, Pliny and Dioscorides. The Babylonian astronomical parameters turned up in Varāhamihira's summary of the five astronomical systems. Although evidence of direct translations of ancient texts is rare, it has come to light that in A.D. 150 one Yavaneśvara translated into Sanskrit prose a Greek astrological text which had been written in Alexandria in the preceding century[3]. The original translation is lost, but a verification of it made in the third century A.D. by Sphujidhvaja has been preserved in Nèpal in a thirteenth century palm leaf transcription.

An abundant literature exists on the subject of Sino-Indian religious and cultural interchange beginning from the time of the Yueh-Chin Dharmarakṣa (3rd-4th century A.D.) and the Kashmirian Kumārajīva (4th-5th century A.D.). In the course of this interchange, several Buddhist scholars, Indian as well as Chinese, were actively engaged in the translation of canonical as well as non-canonical texts, including a large number of works concerning Brahminical (po-lo-mon) astronomy, mathematics, pharmacy and logic. Most of the non-canonical works translated from Sanskrit into Chinese have not survived, but the records of these activities and titles of some of these works have been preserved in the catalogues of the Sui and the Thang Dynasties. The records of the Thang dynasty indicate the existence of an active school of Indian astronomers at Chang-Nan engaged in the teaching and propagation of the Indian *Navagraha* system of astronomy. The

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1. Sen, S. N., 'Influence of Indian Science on other culture areas', *Indian Journal of History of Science*, 5, No. 2, 332-346, 1970.
2. Sen, S. N., 'Transmission of Scientific Ideas between India and foreign countries in ancient, and medieval times', *Bulletin of the National Institute of Sciences of India*, No. 21, 8-30 1963.
3. Pingree, David, 'Astronomy and Astrology in India and Iran', *ISIS*, 54, 229-246, 1963.

records also mention a number of Chinese astronomers, all bearing the name of Chhuthan, a Chinese transcription of the Hindu name Gautama, who compiled astronomical treatises based on Indian elements and even translated Sanskrit calendrical works in Chinese, of which notable examples are the *Chiu-Chi-li* and the *Tai-yen* calendars. Needham observed that, paradoxical as it might appear, the Chinese owed to Indian Chhuthan Hsi-Ta the greatest collection of their ancient and medieval astronomical fragments[4].

Sanskrit works are also known to have played an important role in the foundation of the Arabic literature between A.D. 750-850. Indian works on fables, military and veterinary science, medicine and astronomy were in this way incorporated into the corpus of the Arabic literature. Arabic astronomical renaissance was possibly brought about by the translation of Indian *Siddhāntas*, with which the names of al-Fazārī (*c*.A.D. 750) and Ya'kūb ibn Ṭāriq (*c*.A.D. 770) are intimately associated. Al-Fāzarī was possibly the earliest translator of the *Brahmasphuṭasiddhānta* and Ya'kūb ibn Ṭāriq of the *Khaṇḍakhādyaka*, though this question of the preparation of the earliest *Sindhind* and *Arkand* zijcs is by no means settled[5]. Besides direct translations, several Arabic astronomical tables made use of Indian astronomical elements side by side with those derived from Greek works. Al-Khwārizmī's famous astronomical tables were of this nature and, in their revised versions as prepared by Maslama al-Majrītī, exerted considerable influence among medieval astronomical circles in Spain. These tables were translated into Latin by Adelard of Bath in the twelfth century, and have come down to us only in this Latin version. Likewise, al-Khwārizmī's arithmetic based on Indian sources of which the Arabic version was long since lost has survived only in a Latin translation under the title *Algoritmi de numero Indorum*, discovered in the Cambridge University Library by Prince Baldassare Boncompagni and published by him in his *Truttati d'Arithmatica*, Rome, in 1857.[6]

Among ancient and medieval scholars interested in translating Sanskrit technical works, the most outstanding was without doubt Abū Raiḥān Muḥammad b. Aḥmad al-Bīrūnī (973-1050). Besides his *Description of India* (*Kitāb fī Taḥqūq mā li'l-Hind*) Bīrūnī composed more than twenty books on India which included a number of works representing direct Arabic translations of Sanskrit texts. These translations included astronomical calculations found in the *Brahmasiddhānta*, Varāhamihira's *Laghu Jātaka*, astronomical tables of Vijayānanda (*Karaṇatilaka*), *Pauliśa Siddhānta*, Book of Sāṅkhya, and the Book of Patañjali. Bīrūnī is also known to have prepared a Sanskrit version of Ptolemy's *Almagest*, Euclid's *Elements* and one of his own works on astrolab. He spent about ten years in North-West India, collected a large number of Sanskrit manuscripts and learnt enough Sanskrit to

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4. Needham, Joseph, *Science and Civilisation in China*, III, 1959, p. 203.
5. Kennedy, E.S., 'A Survey of Islamic Astronomical Zijes', *Transactions of the Americal Philosophical Society*, 46, 123-77, 1956.
6. Benedict, Suzan Rose, *A Comparative Study of the Early Treatises introducing into Europe the Hindu art of reckoning*, being a thesis submitted for the Degree of Doctor of Philosophy in the University of Michigan, 1914.

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undertake such ambitious programmes of translation himself with the aid of Pandits and dictionaries. In fact, we hardly come across another Indologist of the stamp of al-Bīrūnī until Sanskrit learning and schools of serious Indological studies became firmly established in the nineteenth century.

Astronomy, Mathematics and Astrology

As mentioned before, the modern study of Hindu astronomy may be said to have commenced with the publication by Giovanni Dominique Cassini of the results of his study of Sanskrit manuscripts in the *Memoires de-l academie Royale des Sciences* (1). The manuscript had been brought to Paris in 1687 by M. de la Loubere who had been sent to Siam on an embassy by Louis XIV. The manuscript contained rules for calculating the motions of the sun and the moon. Cassini gave exact translations in French of several rules given in the manuscript along with an excellent commentary possible only for a great astronomer of his calibre. He showed that the Hindus had taken their year-length to be 365 days 6 hours 12 minutes and 36 seconds, that astronomical constants were given for the epoch which started on Saturday, March 21, 638 A.D., that the period of the revolution of the moon's apsis was 3232 days, and that the greatest equations of the centre for the sun and the moon were 2°12 and 4°56 respectively. From the ratio of the length of a *tithi* to a civil day as 692 : 703 and from 703 lunar months containing 20,760 days, Cassini calculated the length of a synodic month to be 29 days 12 hours 44 minutes and 2.39 S. To give an example of Cassini's treatment of the rule for finding *ahargaṇa* as given in this manuscript, the follwing is cited after Bailly(5):

> " Posez le *maasakcn* : multipliez par 30 ; joirnez les jours du mois courant ; multipliez tout parll ; ajouiez-y 650 ; divisez tout par 703 ; gardez le numerateur que vous appelerez *anaamcn*; prenez le quotient de la fraction trouvez article VI et soustraiez le du nombre trouve art. III. le reste fera l'horoconne (C'est a dire le nombre des jours de l'ere) que vour gardez. "

That is,

> " Set forth the number of months ; multiply by 30 ; add to it the days of the current month ; multiply the whole by 11 ; add to it 650; divide the whole by 703 ; keep the numerator which you call *anaamcn*; take the quotient of the fraction found in article VI and subtract it from the numbers found in art III; the remainder will be the *ahargaṇa* (that is to say, the number of days in the era) which you keep. "

The ratio of 7/228 is taken to be the ratio of intercalary month to *saura* months in a luni-solar *yuga* which implies the use of the Metonic cycle. James Burgess conjectured that the Siamese manuscript was probably based on the *Paulīsa Siddhānta.*[7]

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[7] Burgess, James, 'Notes on Hindu Astronomy and the History of our Knowledge of it', *Journal of the Royal Asiatic Society*, 717 ff., 1893.

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The next important work was due to Le Gentil, another distinguished French astronomer who visited India in 1769 to observe the transit of Venus and utilised this opportunity to study Hindu astronomy. He obtained his information from Brahmin astronomers and faithfully recorded them along with his own explanations and mathematical calculations (2). The work is important for the earlier exposition in an European language of the *Vākyam* process for the computations of solar and lunar eclipses. Some of the elements of the *Sūryasiddhānta* and the *Laghu Āryasiddhānta* are incorporated in this work. In 1777, Robert Barker of the Bengal military service described the masonry astronomical instruments of the Benares Observatory with drawings (3). Descriptions of Jai Singh's observatories at Jaipur, Delhi, Ujjain and other places also appeared in Bernouille's German and French translations of Tieffenthaler's *Description of India*(4).

In 1787 appeared Jean Sylvain Bailly's *Traite de l'Astronomie indienne et orientale* which summarized the earlier findings of Cassini and Le Gentil and utilised new manuscript materials which had accumulated in Paris and remained unnoticed(5). One such manuscript was entitled the *Pañcāṅga Siromaṇi* which had been sent from India in 1750 to M. Joseph de Lisle by the French Jesuit Father Patouillet. Another manuscript used by Bailly was collected in India by Father Xavier du Champ and transmitted to the noted Jesuit astronomer Father Gaubil in China who, unable to study it himself, sent it to M. de Lisle. Bailly's study showed that the equations of the sun and the moon agreed with those given in the *Sūryasiddhānta*, that the constants fitted with the year 499 A.D. and the epoch used started from March 10, 1491. His commentaries and calculations were marked by high scholarship and good understanding of Hindu astronomical procedures, but the work suffered from the author's exaggerated notions regarding the high antiquity of Indian astronomy. But the great merit of the work lay in the interest it was able to generate among astronomers in Europe and elsewhere. This is evident from the series of articles which appeared in 1790 in the *Transactions of the Royal Society of Edinburgh* Vol. 2 and *The Asiatic Researches*, Vol. 2 published by the Asiatic Society of Bengal. In two articles William Jones discussed the chronology of the Hindus(6) in which the astronomical elements were pressed into services as Bailly had done before him and the high antiquity of the Indian zodiac(7) giving translations of relevant passages from Hindu astronomical texts. John Playfair, mathematician-geologist and natural philosopher, published a long dissertation on the astronomy of the Hindus(8), based largely on the works of Cassini, Le Gentil and Bailly. He summarized his own estimate of Hindu astronomy as follows: 'The constructions and these tables imply a great knowledge of geometry, arithmetic and even of the thoretical part of astronomy. But what, without doubt, is to be accounted the greatest refinement in this system, is the hypothesis employed in calculating the equations of the centre for the sun, moon and planets, that *viz.*, of a circular orbit having a double eccentricity, or having its centre in the middle between the earth and the point about which the angular motion is uniform. If to this we add the great extent of geometrical knowledge requisite to combine this, and the other principles of their astronomy together, and to deduce from them the just conclusions; the possession of a calculus equivalent to trigonometry; and lastly, their approximation to the quadrature of the circle, we shall be astonished at the magnitude of that body of science, which must have enlightened the inhabitants of India in some remote age, and which whatever it may have communicated to the Western nations, appears to have received nothing from them'. This reflects the general attitude to Indian astronomy and mathematics towards the end of the 18th century which, however, underwent revision later on with the increase in our knowledge of ancient astronomy.

In 1789, Samuel Davis undertook a study and analysis of a copy of the *Sūryasiddhānta* he obtained through the courtesy of Sir Robert Chambers and published his results in the *Asiatic Researches*(10). In this study he utilised a commentary and noticed a number of Hindu astronomical works, including the *Brahmasiddhānta* forming part of the *Viṣṇudharmottara Purāṇa*, *Pulastya-Soma-Vaṣiṣṭha-Ārya-Romaka-Parāśara-Ārṣa Siddhāntas*, *Sākalya Saṃhitā*, *Grahalāghava*, *Siddhāntarahasya* and *Makaranda Sāraṇī*. Applying Lagrange's formula, he showed that the Hindu value of 24 for the obliquity of the ecliptic answered for the year 2050 B.C. Two years later Davis came out with another important paper dealing with the twelve-year cycle of the Jupiter in which he used the statements contained in the *Sūryasiddhānta*, *Siddhānta Siromaṇi*, *Jyotiṣatattva*, Varāhamihira's works and other texts. About this time Ruben Burrow, an able mathematician and astronomer, then working as an assistant in the Surveyor General's establishement drew attention to the mathematical acumen of ancient Indians(9). With the help of a Pandit, he translated part of the *Bījagaṇita* and the *Līlāvatī* of Bhāskara II, but did not complete the work for publication.

John Bentley's enormous labours with Indian astronomical texts were primarily directed to criticizing Bailly's assumption of the high antiquity of Indian astronomy(12). Basing on certain statements contained in Satānanda's *Bhāsvatī Karaṇa*, he placed Varāhamihira and the *Sūryasiddhānta* in th eleventh century A.D. He furthermore showed that the planets were not in conjunction at the beginning of the Kaliyuga era (February 17-18, 3102 B.C.), the Sun, Mercury, Venus, Mars, Jupiter and Saturn deviating from the initial point of the Hindu ecliptic by as much as—7° 51' 48'',—41° 3' 26'',+24° 58' 59'',—19° 19' 26'',+8° 36' 26'' and —28° 1' 13'' respectively. He calculated the gradual decrease of errors from 3102 B.C. and found on an average the date of planetary conjunctions around A.D. 1091 which accordingly suggested as the approximate date for the compilation of the *Sūryasiddhānta*. Although his approach and some of his arguments deserved considerations, his methods and generalizations were open to serious criticism and failed to receive the acceptance of the scholarly world.

From the beginning of the 19th century, greater emphasis was placed on the search for new manuscripts and their translations and critical studies with a view to attaining a deeper understanding of the Indian methods and procedures. Playfair had suggested such endeavours years back in 1792, but it was left to Strachey, Taylor and Colebrooke to carry out this important task. Strachey's English translation of Bhāskara's *Bījagaṇita* appeared in 1813 (14) and John Taylor published his *Līlāvatī* in 1816. The following year Colebrooke came out with his *magnum opus*, the *Algebra*

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with Arithmetic and Mensuration etc. (17) containing English translations of considerable portions of the *Brahmasphuṭasiddhānta* of Brahmagupta and Bhāskara II's *Līlāvatī* and *Bījagaṇita*. His opening dissertation in which he measured the Indian achievements in algebra and arithmetic with those of the Arabs and the Europeans of ancient and medieval times was a model of high scholarship. Colebrooke's earlier notices on the Indian Arabian zodiac(13) and the Hindu corrections for the precession of the equinoxes(16) were marked by a similar critical appraisal of astronomical texts and penetrating analysis.

In 1825, John Warren, an assistant of Col. Lambton in the Trigonometrical Survey of India, produced his *Kālasaṅkalita*(18), a work compiled on the basis of information supplied to him by Indian astronomers and calendar-makers of South India in somewhat the same manner as Le Gentil had done more than fifty years before him. In the Preface, Warren explained the object of the work as follows : "The whole collectively taken was denominated by some learned friends *Kālasaṅkalita*, a Sungscrete (Sanskrit) word signifying the doctrine of times. It presents (as far as the author knows) the first attempt that was made in India to investigate and explain the elements of Hindu Astronomical chronology, and to disclose to Europeans the contents and structure of those humble annual calendars which, written on palmyra leaves have, during nearly two centuries, been sold under their eyes without ever suspecting the skill and labour which their computations required ". This work discussed, among other things, the method of computing eclipses by means of arranging shells on the ground and with the help of certain tables and a few symbolical words and syllables. In 1952 Neugebauer studied these methods as reported by Warren and discovered in them Babylonian procedures[8].

In 1827, C.M. Whish revived the old question of the antiquity of the Hindu zodiac, examined the works of Varāhamihira, particularly his *Bṛhajjātaka*, Śrīpati's *Ratnamālā* and a commentary on it, and demonstrated Sanskrit transliteration of Greek zodiacal names as also Greek names of a large number of astrological-astronomical technical terms(19). In the 18th century, Father Pons had reported in the *Lettres edifiantes* (26-236-27, 1743) the existence of such words as *horā* and *kendra* in Sanskrit astrological texts. Colebrooke had occasionally referred to such terms, but it was Whish who made the most exhaustive study of the subject to prove Indian borrowings from Greek astrological sources. Equally important was his work on Hindu quadrature of the circle for which he examined a number of medieval Sanskrit astronomical texts such as the *Tantrasaṅgraha*, *Karaṇapaddhati*, *Yuktibhāṣā* and *Sadratnamālā*(20). These texts contained rules and procedures for obtaining Trigonometrical and Infinite series not known in Europe before Gregory.

From 1837 onwards we notice progressive intensification of translation-efforts. Although the *Sūryasiddhānta* and the *Siddhāntaśiromaṇi* were quoted time and again in astronomical discussions, complete translations of them had remained a desideratum. A Marathi translation of the *Siddhānta Śiromaṇi* appeared in 1837 (21). E. Roer published a Latin translation of parts of the text in the *Journal of the Asiatic Society of*

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[8] Neugebauer, O, 'Tamil Astronomy-A study in the history of astronomy in India', OSIRIS, 10, 252-276, 1952.

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Bengal(23), and the translation of the chapter 'Golādhyāya' by Lancelot Wilkinson and Bapudeva Sastri appeared during 1961-62 in the *Bibilotheca India* series. As regards the *Sūryasiddhānta*, a Bengali translation appeared in 1842 (22). Guerin, in his *Astronomie Indienne*, gave a French translation of parts of chapters 1 and 8 (26), and finally Rev. Ebenezer Burgess, an American missionary who had lived for 15 years in the Bombay Presidency, produced an English translation of the whole text in 1860(27). Burgess procured three manuscripts of the *Sūryasiddhānta*, one of them with the commentary *Gūḍhārthaprakāśaka* by Raṅganātha, made the first draft of his translation in India with the assistance of Pandits and the Professor of Mathematics at the Poona Sanskrit College and finalised the work on his return to the U.S.A. where he received valuable suggestions from the distinguished orientalist and Sanskritist Prof. W.D. Whitney and mathematical assistance from Hubert A. Newton of the Yale College. Moreover, in preparing elaborate notes and commentaries which greatly added to the value of the work, he fully utilised the astronomical researches of his predecessors. Burgess' translation of the *Sūryasiddhānta* which has ever since remained a standard and model work of its class, has demonstrated the necessity of co-operation among Sanskritists, orientalists and professional scientists in translating and annotating scientific works of this nature.

After the appearance in 1845 of J.B. Biot's paper[9] on lunar mansions in which he favoured a Chinese origin of the system, the old controversy regarding the antiquity and origin of the zodiac was fully revived, and Indianists like Whitney, Burgess and Weber came forward to defend the case of the *nakṣatras*. Albrecht Weber who had already distinguished himself for his Vedic studies by editing the *White Yajurveda* and the *Śatapatha Brāhmaṇa* and by his numerous contributions to the *Indische Studien* delved deep into the Vedic texts to establish the high antiquity of the *nakṣatras*. The results were his *Die vedischen Nachrichten von den Naxatra*(30) and *Uber den Vedakalendar, Namens Jyotisham*(29), both published in 1862. The *Vedakalendar* discussed the astronomical elements of the *Vedāṅga Jyotiṣa* which receives further treatment at the hands of Georg Thibaut (39) who gave an English translation of a considerable portion of the text. Thibaut also became interested in Vedic Mathematics and published an English translation of Baudhāyana's *Śulba sūtra*(36), (38) with extracts from the commentary of Dvārakanātha Yajvā, demonstrating Indian acquaintance with irrational numbers, the so-called Pythagorean theorem and related matters in the sixth-fifth century B.C. Following Weber's notice of the *Sūryaprajñapati*, a Jaina astronomical work based largely on the *Vedāṅga Jyotiṣa*, Thibaut published an account of it, with translation of several passages, in the *Journal of the Asiatic Society of Bengal*(42).

Varāhamihira's works which never ceased to attract interest received fresh treatment at the hands of H. Kern who edited the *Bṛhatsamhitā* for the *Bibliotheca Indica* 1864-65, published an excellent preface of considerable historical value regarding, astronomers mentioned by Varāha and finally translated the whole text serially in

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[9] Biot, J. B., 'Sur les Nachhatras, ou Mansions de la Lune, selon les Hindoux etc.' *Journal Asiatique*, 39 ff, 1845.

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the *Journal of the Royal Asiatic Society*(32). A Hindi translation was made by Bala Sastri(43) and an English translation, by Chidambaram Iyer(47). Weber and Jacobi produced German translations of his *Laghujātaka* (23, 34). George Thibaut again rendered a unique service by first giving an account of Varāhamihira's *Pañcasiddhāntika*(46), of which a manuscript was discovered by G. Buhler, and then publishing, in collaboration with Sudhakara Dvivedi, a full translation and a Sanskrit commentary(48).

Another important event of this period was the publication by H. Kern from Leiden in 1874 of the *Āryabhaṭīya*, with the commentary *Bhaṭadīpikā* by Parameś-vara, the work which was hitherto known only in quotations and excerpts from other astronomical texts and commentaries. In 1879, Leon Rodet translated into French the chapter 'Gaṇitapāda' (41), containing mathematical rules essential for performing various astronomical computations. The great progress achieved in the understanding of Hindu astronomy, astrology and mathematics during the last two centuries was admirably summarized in a paper 'Astronomie, Astrologie and Mathematik' by Georg Thibaut who had himself advanced this knowledge to a great extent by his researches referred to above[10].

Medicine

Sanskrit medical texts such as the samhitās of Caraka and Suśruta were translated into Arabic in the 8th century A.D., according to the evidence of Ibn al-Baitar, al-Bīrūni and Abu Usaibiah. Hindu physicians are also known to have worked in the hospitals of Baghdad and translated from Sanskrit into Arabic books on medicine, pharmacology, toxicology and other subjects[11]. That Indian physicians were held in high esteem is corroborated by the repeated mention of Caraka in the Latin translations of Ibn Sina, al-Razi and Ibn Serabi[12]. Modern notices on Indian medicine, however, started appearing from the early part of the 19th century, when Ainslie published his *Materia Medica of Hindostan* in 1813. Wilson in 1823 reported on the medical and surgical sciences of the Hindus in his *Essays on Sanskrit Literature*; Royle in 1839 published *An Essay on the Antiquity of Hindoo Medicine*; and Wise produced his *Commentary on the Hindoo System of Medicine*[13]. Interest in Indian medicine was kept alive by similar notices and articles by Stenzler, Lassen, Weber, Lietard and several others. Another contributing factor was the opening in 1826 of Medical Classes at the Sanskrit College, Calcutta, with the express purpose of training physicians according to the Hindu system of medicine and surgery.

The first edition of a medical text, that of *Suśruta Samhitā* was prepared by Madhusudan Gupta and published from Calcutta during 1835-36. A Latin translation of this medical text was produced by Hessler during 1844-52(24), followed shortly by a German translation by Vullers(25). The Latin translation became soon obsolete. For a reliable translation of the *Suśruta Samhitā* one had to wait till 1883 when Uday Chand Dutt commenced translating the text into English in the *Bibliotheca Indica* and Aghore Chunder Chattopadhyaya continued the work upto 1891(45). Even then the work remained incomplete. In 1897 Hoernle translated the book upto 1, 14, which was published in the *Bibliotheca Indica.* In 1876, A.M. Kunte edited Caraka giving at the same time a translation of a few chapters of Suśruta. The complete translation was made available only in the beginning of the present century by Kaviraj Kunja Lal Vishagratna. Cordier's *Nāgārjuna et Uttaratantra de la Suśruta Samhitā* is an important contribution to the subject(51).

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[10] Thibaut, George, 'Astronomie, Astrologie und Mathematik', *Grundriss der Indo-Arischen Philologie und Altertumskunde*, III, 9, 1897.

[11] Sachau, E., *Alberuni's India*, Preface, xxxi-xxxii.

[12] Weber, A. *The History of Indian Literature*, 1875, p. 271.

[13] Jolly, Julius, "Medicine', *Grundriss der Indo-Arischen Philologie und Altertumskunde*, III. 10. p. 19.

The same story is repeated with regard to the translation of the *Caraka Samhitā* An edition of *Caraka* was started by Gangadhara Kaviraj in Calcutta during 1868-69 but could not be completed by him. Mahendralal Sircar published a translation of a few chapters in English in 1870(31) and Roth published a German translation of sections 3, 8 and 1, 29 in the *ZDMG*(35). The complete English translation of this voluminuous compendium was due to Kaviraj Avinash Chandra Kaviratna and his son Pareshnath Sarma-Kavibhusana ; these two physicians really acted as editors, the real translator being Kisori Mohan Ganguly(49). The translation, in the opinion of Jolly, is involved and not always reliable.

In 1890, Lt. H. Bower discovered in a Buddhist stupa in Kutch in Kashgar some old Indian medical manuscripts written in incorrect Sanskrit mixed with Prākṛt. The Bower Manuscripts known after the name of their discoverer were edited and translated into English by Hoernle(50) and also became the subject of intensive scholarly discussions by Hoernle, Buhler, Jolly, Oldenberg and others.

During the 19th century, following a growing practice in Ayurvedic medicine, large number of works on *materia medica,* in Sanskrit and English, were published. The most important of them was Uday Chand Dutt's *The Materia Medica of the Hindus*(40), compiled from Sanskrit medical works and published from Calcutta in 1877. Of medico-botanical glossaries, the 13th chapter of Narahari's *Rājanighaṇṭu,* dealing with minerals, was translated into German by R. Garbe under the title *Die indischen Mineralien*, Leipzig, 1882(44).

Translation of Scientific Works into Sanskrit

Our information regarding the efforts made during the 18th and the 19th centuries in translating scientific works in foreign languages into Sanskrit is meagre. At the beginning of the 19th century, Jagannātha, principal astronomer of Jai Singh, the builder of astronomical observatories at Delhi, Jaipur, Ujjain and other places, translated Ptolemy's *Almagest* and Euclid's *Elements* from Arabic into Sanskrit under the titles *Samrāṭ siddhānta* and *Rekhāgaṇita.* Hunter records that at Ujjain he met a grand-son of Jagannātha, who had in his possession several Sanskrit translations of European mathematical works, including plane and spherical

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trigonometry and Napier's logarithms[14]. Jai Singh's own little work entitled *Tantrarāja* dealing with the construction and theory of astrolabs appears to be either a translation of, or based, on, some Arabic or Persian work on the subject. Nayanasukhopādhyāya's *Ukarākhyagrantha* is a treatise on spherical geometry translated by him with the help of one Abid from Arabic into Sanskrit[15]. Late Bapudeva Sastri (1821-90) who collaborated with Lancelot Wilkinson in editing and translating *Siddhānta Śiromaṇi* was an enthusiastic translator of European elementary mathematical works into Sanskrit and produced a number of tracts on geometry, trigonometry and astronomy[16].

The establishment of the Native Medical Institution in 1824 and the opening of Medical Classes in 1826 at the Sanskrit College and the Madrassah at Calcutta created a need for translating European medical text books into Sanskrit and other Indian languages. Some of the books selected for translation and lithographed at Government expense include the following : (1) Hooper's *Anatomists' Vade-mecum, Physicians' Vade-mecum* and *Surgeons' Vade-mecum* (2) Thomson's *Conspectus of the Pharmacopoeia* (3) Fyfe's *Manual of Chemistry* (4) Twining and Smith's *Tropical Diseases* (5) Conquest's *Outline of Midwifery* (6) Thomas' *Plague* and (7) *A Book of Vaccination*[17]. In 1834 Pandit Madhusudan Gupta was paid Rs. 1000 for translating Hooper's *Anatomists' Vade-mecum*. The work was completed under the title *Śarīravidyā* and taken up for publication by the Asiatic Society in 1835 ; but the publication was abandoned after a few pages had been printed on account of a cut in the Society's grant for publication of oriental books as a sequel to the controversy then raging between the Anglicists and the Orientalists.[18]

The early emphasis on the writing of medical books in Indian languages for students of the Native Medical Institution and the Medical Classes of the Sanskrit College and the Madrassah and the decision to re-establish Bengali medical classes at the Calcutta Medical College soon after its foundation created a congenial climate for the production of medical books in Bengali. Some of the books published in this period include Ram Komul Sen's *Aushadh Sar Sangraha* (1819), Cary's *Vidya Haravali* (dealing with anatomy and based on the article of the *Encyclopaedia Britannica*, 5th edition, (1820) Breton's *A Vocabulary of Medical Terms* (1823) (giving Persian, Sanskrit and Bengali medical terms and involving much research), Breton's *Ula Uta Bibaran*, a book on cholera (1826), *Utpati Nirbaha*, an anonymous work on foetus, based on Ayurveda (1826), Prankrishna Biswas' *Ratnabali* or Medical Manual (1833), Iswar Chandra Bhattacharya's *Drabya Guna*, qualities of indigenous medicine being translation from Sanskrit works (1835), Madhusudan Gupta's *Aushadh Kalpaballi* (1849) (a Bengali translation of the London

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14. Sen, S. N., 'Astronomy' in *A Concise History of Sciences in India*, Indian National Secince Academy, 1971, p. 103.
15. Sen, S.N., *A Bibliography of Sanskrit Works on Astronomy and Mathematics*, Indian National Science Academy, 1966, p. 153.
16. Dvivedi, Sudhakara, *Gaṇakataraṅgiṇī*, p. 127,
17. *Centenary of the Medical College of Bengal*, p. 4.
18. *Centenary Volume of the Asiatic Society*, Part I, pp. 58-59.

Phamacopoeia (giving methods of preparations of acids, alkalis, cerates, confections, plasters, infusions, metals, pills, powders, syrups, tinctures, ointments etc.), Raj Krishna Mukherjea's *Atmarakhya* (1849), Srinarayan Ray's *Ayurveda Darpan* (1852) (giving translations from Caraka and Suśruta on various diseases and their cures), Haladhar Sen's *Cikitsa Ratnakar* (1853), P. Kumar's *Aushadh Byavaharak*, Bengali translation of Practice of Medicine (1854) and Ananda Chandra Barman's *Sar Kaumudi*, a *materia medica*, translated from the Ayurveda (1855). For references to more works of this nature, Long's *A descriptive Catalogue of Bengali Works* (1855) is a valuable guide.

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Table showing Sanskrit Works- Names of Translators, Language of Translation, References etc.

Sr. No.	*Year*	*Subject*	*Sanskrit Author*	*Text Title*	*Translator*	*Language*	*Reference to Publication*
(1)	1691-1699	Astronomy	Anonymous	A manuscript of Hindu system of astronomy sent to Paris by M. de la Loubere of the French Embassy to Siam in 1687.	Giovanni Domonique Gassini	French	*Memoires de l 'Academic Royal-des Sciences*, 1699, 8, 279-362. The Memoires originally appeared in de la Loubere's *Relation de Siam II*.
(2)	1772	Astronomy	..	Based on oral instructions received from Tamil astronomers and calendar-makers	Le Gentil	French	'Memoires sur 1 'Astronomie des Indiens', *Histoire de 1 'Academie Royale des Sciences*, 1772, 2nde partie, 169-189; 190-214; 221-266.
(3)	1777	Astronomy	..	Description of astronomical observatory	Robert Barker	English	'Brahmin's Observatory at Benares, *Philosophical Transactions of the Royal Society*, 67, 598-607.
(4)	1785-1789	Astronomy	..	Description of Jai Singh's Astronomical Observatories.	Father Joseph Tieffenthaler (translated by Jean Bernouille)	Latin	*Das Pater Joseph Tieffenthalers historisch-georgraphische*
						German	*Beschreibung von Hindustan*, Berlin, 3 vols. 1785-87.
						French	*Description historique et geographique de l'Inde*, 3 vols. 1786-89.
(5)	1787	Astronomy		Based on materials published by Cassini and Le Gentil; two new manuscripts, one of them *Pancāṅga Śiromaṇi*, other not mentioned.	Jean Sylvain Bailly	French	*Traite de l'Astronomie indienne et Orient-ale*—ouvrage qui peut servir de suite a l'Histoire de l'Astronomie ancienne, Paris, 1787.

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(6)	1790	Astronomy	..	..	William Jones	English	'On the Chronology of the Hindus', *Asiatic Researches* II, 111-147; suppl. 389-403 1790
(7)	1790	Astronomy		..	do.	do.	'On the Antiquity of the Indian Zodiack', *Asiatic Researches* II, 289-306, 1790.
(8)	1790	Astronomy		English exposition of the works of Cassini, Le Gentil and Bailly.	John Playfair	English	'Remarks on the Astronomy of the Brahmins' *Transactions of the Royal Society of Edinburgh*, II, 135-192, 1790.
(9)	1790	Mathematics		..	Ruben Burrow	English	'A Proof that the Hindus had Binomial Theorem', *Asiatic Researches*, II (App. 5), 487-497, 1790.
(10)	1790	Astronomy		Based on *Sūryasiddhānta*.	Samuel Davis	English	'On the Astronomical Computations of the Hindus', *Asiatic Researches* II, 225-287, 1790. (A critical analysis of the element of the *SS* in the course of which six astron. mss. previously unnoticed in European languages are mentioned and utilized).
(11)	1792	Astronomy		Based on *Sūryasiddhānta*, Varāhamihira, *Siddhāntatattvaviveka Siddhānta Śiromaṇi*.	Samuel Davis	English	'On the Indian Cycle of Sixty Years' *Asiatic Researches*, III, 1792.
(12)	1799	Astronomy		Based on *Sūryasiddhānta*.	John Bentley	English	'On the Antiquity of the *Sūrya-Siddhānta* and the formation of

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
							the astronomical cycles therein contained', *Asiatic Researches*, VI, 537-588, 1790 (Analytical work with translation of passages as required).
(13)	1807	Astronomy		..	Henry Thomas Colebrooke	English	'On the Indian and Arabian Divisions of the Zodiack', *Asiatic Researches*, IX. 323-376, 1807. Also his *Essays*, II 321-376. (Several Sanskrit texts cited with translations of extracts).
(14)	1813	Mathematics	Bhāskara II	*Bījagaṇita*	E. Strachey	English	*On the Algebra of the Hindus*, 119, pp. London, 1813.
(15)	1816	Mathematics	Bhāskara II	*Līlāvatī*	John Taylor	English	*The Lilawati or a treatise on Arithmetic and Geometry by Bhascara Acarya*, translated from the original Sanskrit, 161 pp., Bombay, 1816.
(16)	1816	Astronomy			Henry Thomas Colebrooke.	English	'On the Notions of the Hindu Astronomers concerning the Precession of the Equinoxes and motions of the Planets', *Asiatic Researches*, XII, 209-250. 1816. Also his *Essays*, II, 374-416.
(17)	1817	Mathematics	Brahmagupta Bhāskara II	*Brahmasphuṭasiddhānta* (chapters dealing with gaṇitādhyāya and kuṭṭakādhyāya only). *Līlāvatī* & *Bījagaṇita*.	Henry Thomas Colebrooke.	English	*Algebra with Arithmetic and Mensuration from the Sanskrit of Brahmagupta and Bhāskara*, London, 1817.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(18)	1825	Astronomy	..	..	John Warren	English	*Kālasaṅkalita,* A collection of Memoires on the various modes according to which the natives of the southern parts of India divide time. Madras, 1825.
(19)	1827	Astronomy	Varāhamihira Śrīpati	*Bṛhajjātaka* *Ratnamālā*.	C. M. Whish	English	'On the Antiquity of the Hindu Zodiack', *Transactions of the Madras Literary Society,* 1827. Translated by Lassen in *Zoitsch. f. d. Kunde d. Morgenl.,* IV, 302 ft. (reproduces from the texts several astronomical-astrological terms originally used in Greek).
(20)		Mathematics		*Tantrasamgraha, Yuktibhāṣā, Karaṇapaddhati Sadratnamālā*.	C. M. Whish	English	'On the Hindu Quadrature of the Circle and the Infinite Series of the Proportion of the circumference to the diameter exhibited in the four Shastras, the *Tantrasamgraha, Yuktibhāṣā, Karaṇapaddhati* and *Sadratnamālā*', *Transactions of the Royal Asiatic Soecity of 'Great Britain and Ireland,* 3, 509-523 (translations of relevant passages given with mathematical interpretations).
(21)	1837	Astronomy	Bhāskara II	*Siddhāntaśiromaṇi* *Sūryasiddhānta*.	..	Marathi	*Siddhānta Śiromaṇi Prakāsa,* Bombay, 1837.
(22)	1842	Astronomy	..	*Sūryasiddhānta*	..	Bengali	*Sūrya Siddhānta,* with Bengali translation, Calcutta, 1842.
(23)	1844	Astronomy	Bhāskara II	*Siddhānta Śiromaṇi*	E. Roer	Latin	'Bhascarae Acharyae Siddhanta Shiromani sic dicti operis pars

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
							tertia, Ganitadhiam, Sive astronomium continens, Latine vertit notasque adjacit, E. Roer', *Journal of the Asiatic Society of Bengal*, 13, pt. 1, 53-66, 1844.
(24)	1844-1852	Medicine		*Suśruta Samhitā*	F. Hessler	Latin	*Susrutas*, Erlangen, 1844-52 Now obsolete.
(25)	1846	Medicine		*Suśruta Samhitā*	J. A. Vullers	German	Altindische Gebartshilfe aus Susrutas System der Medizin, ubersetzt and erlautert von J. A. Vullers Giessen, 1846 (from the periodical *Janns*, I, 225 ff. 1846).
(26)	1847	Astronomy		*Sūrya Siddhānta*	Abbe J. M. F. Guerin	French	*Astronomie indienne*, Paris, 1847 (parts of 1st and 8th chapters only).
(27)	1860	Astronomy		*Sūrya Siddhānta*	Rev. Ebenezer Burgess	English	'Translation of the *Sūrya Siddhānta*- a Text Book of Hindu Astronomy, with notes and an appendix', *Journal of the American Oriental Society*, VI, 141-498.
(28)	1860-1862	Astronomy	Bhāskara II	*Sūrya Siddhānta* *Siddhānta Śiromaṇi*	Lancelot Wilkinson Bapudeva Sastri	English	*Sūrya Siddhānta and Siddhānta Śiromaṇi*, Bibliotheca Indica, No. 32, Calcutta, 1860-62.
(29)	1862	Astronomy		*Vedāṅga Jyotiṣa*	Albrecht Weber	German	'..Uber den Vedakalendar, Namens Jyotisham', *Abhandlung, d. konigl. Akad. der Wissensch. zu Berlin*, 1862,

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(30)	1862	Astronomy			Albrecht Weber	German	*Die vedischen Nachrihten von den Naxatra*, Berlin, 1860-62.
(31)	1870	Medicine		*Caraka Samhitā*	Mahendralal Sircar	English	Translated a few chapters, *Calcutta Journal of Medicine* (Jolly, *Medicine*, 12).
(32)	1870-75	Astronomy-Astology	Varāhamihira	*Bṛhatsamhitā*	H. Kern	English	'The *Bṛhatsamhitā* or Complete System of Natural Astrology of Varāhamihira, *Journal of the Royal Asiatic Society*, 1870-75.
(33)	1872	Astrology	Varāhamihira	*Laghujātaka*	A. Weber	German	Text and translation of chapters I and II, *Indischen Studien*, II, 1872.
(34)	1872	Astrology	Varāhamihira	*Laghujātaka*	H. Jacobi	German	Text and translation of chapters III to XII under the title 'De astrologiae Indicae "Hora" appallatae originibus accedunt Laghu-Jatakas capita inedita III-XII, Diss., Bonnae, 1872.
(35)	1872	Medicine		*Caraka Samhitā*	Roth	German	Translated sections 3, 8 and 1, 29, *ZDMG*, 26, 442 ff. 1872.
(36)	1875	Mathematics		*Śulba-sūtras*	George Thibaut	English	'On the Sulvasutras,', *Journal of the Asiatic Soiety of Bengal*, 44, (1), 227-275, 1875.
(37)	1875	Astrology	Pṛthuyaśas	*Horāṣaṭpañcāśikā*		Bengali	Published with a commentary and Bengali translation, Calcutta, 1875.
(38)	1874-1877	Mathematics	Baudhāyana	*Baudhāyana Śulba*	George Thibaut	English	'Baudhāyana Śulba, with English translations, critical notes, extracts from the commentary

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(1)	(2)	(3)	(4)	(5)	(6)	(2)	(8)
							of Dvarakanatha Yajva and a few diagrams', *Pandit*, old series 9 & and 10, 1874-75; new series 1, 1877.
(39)	1877	Astronomy		*Vedāṅga Jyotiṣa*	George Thibaut	English	'Contributions to the explanation of Jyotisha-Vedanga', *Journal of the Asiatic Society of Bengal*, 46, (1), 411-437, 1877.
(40)	1877	Medicine		*Materica Medica*	Uday Chand Dutt	English	*The Materia Medica of the Hindus*, compiled from Sanskrit medical works, Calcutta, 1877.
(41)	1879	Mathematics	Āryabhaṭa	*Gaṇitapāda*	Leon Rodet	French	'Aryabhatiye ganitapadah, Lecons de Calcul d'Aryabhata', *Journal Asiatique*, 13, 393-434, 1879.
(42)	1880	Astronomy		*Sūryaprajñapti*	George Thibaut	English	'On the *Sūryaprajñapti*', *Journal of the Asiatic Society of Bengal* 49, (1), 107-127, 181-206, 1880,
(43)	1880	Astrology	Varāhamihira	*Bṛhatsamhitā*	Bala Sastri	Hindi	*Bṛhatsamhitā* with a Hindi translation, Benares, 1880.
(44)	1882	Medicine	Narahari	*Rājanighaṇṭu*	R. Garbe	German	*Die indischen Mineralien*, Leipzig, 1882.
(45)	1883- 1891	Medicine do.		*Suśruta Samhitā* do.	Uday Chand Dutt Aghore Chunder Chattopadhyaya	English do.	*The Suśruta Samhitā*, Bibliotheca Indica. Continued the translation after U.C. Dutt, Calcutta, 1891.
(46)	1884	Astronomy	Varāhamihira	*Pañcasiddhāntika*	George Thibaut	English	'Notes from Varāhamihira's *Pañcasiddhāntika*', *Journal of the Asiatic Society of Bengal*, 53, (1), 259-293, 1884.

(1)	(2)	(3)	(4)	(5)	(6)	(2)	(8)
(47)	1884	Astrology	Varāhamihira	*Bṛhatsamhitā*	Chidambaram Iyer	English	Madura, 1884 (Reference Thibaut, *Astronomie*, 66).
(48)	1889	Astronomy	Varāhamihira	*Pañcasiddhāntika*	George Tribaut Sudhakara Dvivedi	English	*The Pañcasiddhāntika*, the text edited with an original commentary in Sanskrit and an English translation and Introduction, Benares 1889.
(49)	1891-99	Medicine		*Caraka Samhitā*	Kaviraj Avinash Chandra Kaviratna	English	Complete English Translation of *Caraka Samhitā*, Calcutta, 1891-89 (Completed by his son Pareshnath Sarma Kavibhusana and completed in 1911. According to Winternitz, actual translator was Kishori Mohan Ganguli, III, Pt. 3, 630, tr. Subhadra Jha).
(50)	1893-1912	Medicine		Bower Manuscript	A. F. R. Hoernle	English	The Bower Manuscripts Faczimile Leaves, Nagari Transcript, Romanized transliteration and English translation with notes, *Archaeological Survey of India*, Vol. 22, Calcutta, 1893-1912.
(51)	1896	Medicine		*Suśruta Samhitā*	P. Cordier	French	'Nagarjuna et Uttaratantra de la Susruta Samhita, Anantarivo, 1896.
(52)	1897	Medicine		*Suśruta Samhitā*	A. F. R. Hoernle	English	*Suśruta Samhitā*, Bibliotheca Indica 985, upto 1, 14, Calcutta, 1891.

VṚKṢĀYURVEDA OR HORTICULTURAL PRACTICES AMONG THE ANCIENT HINDUS

E.G.K. Rao

Varāhamihira's monumental work' *Bṛhatsamhitā* has a chapter called the 'Vṛkṣāyurveda" (ch. 55), literally meaning the 'Science of Health of Trees' containing some very interesting horticultural practices recommended by the ancient Hindu savants. The chapter is a relatively short one in 31 verses dealing with the laying out and maintenance of parks and pleasure-gardens on the banks of lakes and reservoirs, and the care of the trees and plants. Among the several intersting practices is a detailed description of preparing plant nutrient solutions or 'Tree-tonics" using waste of surplus meat and grain-products. There are also methods of treatment of diseases or plants and inducing the sprouting of certain types of seeds considered normally refractory. The chapter is worth more than a passing interest not only for plant-scientists and commercial orchardists but also for lay lovers of plant-life.

The introductory verse says: " Since the unshaded banks of lakes and reservoirs are not very attractive, parks and gardens should be established in these places."[1]

Treatment of the soil

" Since a soft and mellow soil is beneficial to all types of trees, sesamum should be sown in places where they are to be planted, and when these sprout and come into flower they should be trampled and incorporated with the soil. This is the first treatment to be rendered to soils."[2]

Bhaṭṭotpala commenting on this verse quotes Kāśyapa's verse which says: 'land on which Dūrvā grass (Cynodon dactylon = Bermuda grass) and Vīraṇa (Andropogon Muricatus = Cuscus grass) are found flourishing is soft and mellow and should be planted with good trees of medicinal or economical importance"[3]. This verse simply states the basis for selecting good productive soils. It would also seem that green manuring, as a technique for improving the soil-texture, came to be realised only during the time of Varāhamihira.

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1. प्रान्तच्छायाविनिर्मुक्ता न मनोज्ञा जलाशयाः ।
यस्मादतो जलप्रान्तेष्वारामान् विनिवेशयेत् ॥ १ ॥

2. मृद्वी भूः सर्ववृक्षाणां हिता तस्यां तिलान् वपेत् ।
पुष्पितान् तांश्च मृद्नीयात् कर्मैतत् प्रथमं भुवः ॥ २ ॥

3. दूर्वावीरणसंयुक्ता सानूपा मृदुमृत्तिकाः ।
तत्र वाप्यः शुभा वृक्षाः सुगन्धिफलशाखिनः ॥ २ का ॥
[का refers to Utpala's quotations from Kāśyapa].

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Trees considered suitable for initial planting are given in the verses that follow:

" Ariṣṭa (Melia azadirachta = the Neem tree ; also Sapindus trifoliatus=the Soap-nut tree) ; Aśoka (Saraca indica) ; Punnāga (Mesua ferea = Cobra-saffron tree; also Rottlera tinctoria=Kamala-dye tree) ; Śirīṣa (Albizzia odorotisma. Acacia speciosa); with the Priyaṅgu creeper (Prunus mahaleb, also Aglaia roxburgiana) ; are suitable for initial planting in parks and dwellings."[4]

Kāśyapa's verse quoted by Bhaṭṭotpala[5] introduces three additional trees, Campaka (Michelia champak) ; Udumbara (Ficus glomerata=the cluster-fig) ; and Pārijāta (Nyachtanthes arbor-tristes = the night jasmine). The trees mentioned have either medicinal or aesthetic but not too high a commercial value. They are considered suitable for parks, pleasure-gardens, temples and houses.

Trees and plants suitable for vegetative or asexual propagation-methods

The methods of asexually propagating trees and plants seem to have been well understood by the ancient Hindus. The plants which might be advantageously propagated by such techniques are listed in verses 4 and 5 [6]. The technique is known as ' kāṇḍaropya' literally, "establishing the stems. "

"Panasa (Artocarpus integrifolia—The Indian jack tree); Aśoka; Kadalī; Jambū (Eugenia jambos, E. Jambolana); Lakuca (Artocarpus lakoocha); Dāḍima (Punica granatum—Pomegranate); Drākṣā (Vitis vinifera—the Grape); Pālīvata (Cinnamon um zeilanica—Cassia cinnamon); Bījapūra (Citrus medica=the Citron); Atimuktaka (Ougenia Dalbergioides, Dalbergia ougeinensis)"[6]

Since it is usual to add suffixes like 'ka' in Sanskrit, 'atimuktaka' just means 'atimukta'. In *Amarakośa*, Atimukta is grouped with Puṇḍraka, Vāsantī and Mādhavīlatā. Maheśvara, the commentator on *Amara* says that these apply to varieties of 'Kunda' (Kundabhedāḥ). Kunda is Jasminum pubescens. It is possible that here Jasmine is intended.

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[4] अरिष्टाशोकपुन्नागशिरीषाः सप्रियङ्गवः ।
मङ्गल्याः पूर्वमारामे रोपणीयाः गृहेषु वा ॥ ३ ॥

[5] अशोकचम्पकारिष्टपुन्नागाश्च प्रियङ्गवः ।
शिरीषोदुम्बराः श्रेष्ठाः पारिजातकमेव च ॥
एते वृक्षाः शुभा ज्ञेयाः प्रथमं तांश्च रोपयेत् ।
देवालये तथोद्याने गृहेषूपवनेषु च ॥ ३ का ॥

[6] पनसाशोककदलीजम्बूलकुचदाडिमाः ।
द्राक्षापालीवताश्चैव बीजपूरातिमुक्तकाः ॥ ४ ॥
एते द्रुमाः काण्डरोप्याः गोमयेन प्रलेपिताः ।
मूलोच्छेदेऽथवा स्कन्धे रोपणीयाः परं ततः ॥ ५ ॥

Kāśyapa's verse quoted by Bhaṭṭotpala while commenting on this verse introduces a new plant 'Bahula' which is a variety of cardamom (Amomum subulatum, also A. Xanthoroides.).[6a]

It is also given in the verses that the clones should be treated with cow-dung paste before planting out or rooting. This is a widely followed practice by our traditional orchardists.

The next verse lays down the best season for taking out the clones according to the state of development.

"The clones that have not put forth their branching buds should be separated during the season of the dews (Śiśirartu *i.e.* Māgha-Phalguna=mid-Jan. to mid-March); those that have sprouted the branch buds should be separated for mounting during the cold season (Hemanta *i.e.* Mārgaśīrṣa-Puṣya=mid-November to mid-January); those that have well-developed branches should be affixed on host trees at the start of the rains (Varṣā-kāla or Prāvṛt-kāla, Śrāvaṇa or around mid-June). Alternate readings recommend that those that have just sprouted branching buds should be mounted at the start of the rainy season and those that have well-developed branches should be separated and mounted in the middle of the rainy season (Varṣā-garbhe)"[7]. Varāhamihira further suggests that the clones should be mounted on host trees facing the same direction as they did on the parent trees from which they were separated. The tendency of the clone to preserve the directional character of growth is usually inherited from the parent tree and this has been observed to be very striking in the case of rubber trees in Siberia by the present writer. The verse from Kāśyapa which is quoted by Bhaṭṭotpala[8] does not contain this direction of preserving the directional alignmnt of the clone on the parent tree. From this, it might be fair to infer, that this point was not consciously observed by horticulturists at the time of Kāśyapa.

Treatment of the clones before grafting

It is well known that many grafts fail because of fungal and others infections. It is interesting to note that the ancient Hindus were aware of the need to guard against infection.

[6a] द्राक्षातिमुक्तको जम्बूबीजपूरकदाडिमाः ।
कदलीबहुलाशोकाः काण्डरोप्याश्च वापयेत् ॥
अन्येऽपि शाखिनो ये च पुष्पिताः फलितास्तथा ।
गोमयेन प्रलिप्ताश्च रोपणीया विवृद्धये ॥ ४-५ का ॥

[7] अजातशाखान् शिशिरे जातशाखान् *हिमागमे ।
**वर्षागमे च सुस्कन्धान् यथा दिक्स्थान् प्ररोपयेत् ॥
* *"वर्षागर्भे" इति पाठान्तरम् *"घनागमे" इति पाठान्तरम्

[8] अजातशाखा ये वृक्षा शिशिरे तांश्च रोपयेत् ।
जातशाखाश्च हेमन्ते रोपणीया विधानतः ।
सुस्कन्धाः शाखिनो ये तान् प्रावृट्काले तु रोपयेत् ॥ ६ का ॥

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"The clones should be smeared all over with a medication of Ghee (clarified butter), Uśīra (Andropogon muricatus), Sesame (Sesamum indicum), Viḍaṅga (Embelia ribes), milk, and cow-dung before their transgrafting or transplanting."[9], [9a]

The manner of compounding the medication has not been given. The herbal ingredients are Andropogon, Sesame and Viḍaṅga. All these are described at some length in Dr. Nadkarni's *Indian Materia Medica* and Embelia ribes of these is noted to be a well-known anthelmintic, vermifuge, carminative etc. The parts used are Berries or fruit, leaves and root-bark. Constitutents are Embelic acid, a volatile and fixed oil, colouring matter, tannin, a resinoidal body, and an alkaloid called Christembine. Much work has been done on the derivative of this herb. A colourless crystalline constituent called Viḍaṅgin has also been separated. The purpose of the above treatment is no doubt for prohpylaxis, and ensuring protection from fungal infection etc. Other varieties of Embelia have also been listed, which also share the anthelmintic virtues of Viḍaṅga. The next verse emphasises the need for scrupulous cleanliness and care in performing the operation.

"Having cleansed oneself, the tree should be worshipped and bathed after which the medicated pastes may be applied. Planted in this manner the clone will flourish without any set back."[10]

It is characteristic of Sanskṛit Śāstras that whenever the ancient savants wished to emphasise a highly desirable or mandatory practice, they attached to it a ritual of worship, which is apparently a more effective measure than coercive steps, particularly among the superstitious peasantry. The hints for irrigation-intervals is contained in the next verse.

"During summer, the newly established plants should be given water in the morning and evening; during winter on alternate days; and during rains whenver the grounds is dried up."[11]

Trees and Plants suitable for Cultivation in Low-lying Valley Land

"Jambū (Eugenia jambos, E. Jambolana); Vetasa (Calamus rotang,=the cane palm); Vānīra (A variety of cane palm, or perhaps, C. diversiflora); Kadamba (Anthocephalus Cadamb); Udumbara (Ficus. glomerata=cluster-fig); Arjuna

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9. घृतोशीरतिलक्षौद्रविडङ्गक्षीरगोमयैः ।
अमूलस्कन्धलिप्तानां सङ्क्रामणविरोपणम् ।। ७ ।।

9a. घृतं क्षीरं तथा क्षौद्रमुशीरतिलगोमयैः ।
विडङ्गलेपनं मूलात् सङ्क्रामणविरोपणम् ।। ७ का ।।

10. शुचिर्भूत्वा तरोः पूजां कृत्वा स्नानानुलेपनैः ।
रोपयेद्रोपिताश्चैव पत्रैस्तैरेव जायते ।। ८ ।।

11. सायं प्रातश्च घर्मर्तौ शीतकाले दिनान्तरे ।
वर्षासु च सुवः शोषे सेक्तव्या रोपिता द्रुमाः ।। ९ ।।

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(Terminalia Arjuna); Bījapūra (Citrus medica—the citron); Mṛdvīkā (Vitis vinifera grape); Dāḍima (Pomegranate); Vañjula (Aśoka, Dalbergia); Naktamālā Pongamia glabra); Tilaka ('Cinnamonum iners; C. Malabaricum=wild cinnamon); Panasa (Artocarpus integrifolia); Timira (Timiṣa=Benincasa cerifera=Ash pumpkin; Āmrātaka (Spondias mangifera=Indian hog-plum). These are the trees that are suitable for well-watered low-lying valley type land."[12]

All the above plants have both aesthetic and medicinal values which are described in Dr. Nadkarni's *Materia Medica.* The ancient Hindus were aware of the importance of proper plant-spacing.

"The best planting distance is 20 cubits (30 feet); 16 cubit-spacing may be tolerable; but spacing of 12 cubits and less from tree to tree is not desirable"[13].

"Trees that are planted so close that their canopies touch will not yield since they cause them to be mutually tortured on account of their root-systems intertwining."[14]

Causes of Diseases and their Treatment

"Cold air, disturbances in the atmosphere, and lack of hot sunshine cause disease which may be recognised by the pallor in the foliage and its scantiness, sparcity or absence in the generation of new shoots, wilting or drying up of the branches, or bleeding sores in any part of the tree."[15]

"The treatment of the diseased trees can be accomplished by excising the diseased portions with a suitable tool, and applying a paste of Viḍaṅga (Ebelia ribes), ghee and mud and spraying the whole plant with a mixture of milk and water, which will result in curing the diseases."[16]

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[12] जम्बूवेतसवानीरकदम्बोदुम्बरार्जुनाः ।
बीजपूरकमृद्वीकालकुचाश्च सदाडिमाः ॥ १० ॥
वञ्जुलो नक्तमालाश्च तिलकाः पनसास्तथा ।
तिमिरोऽम्रातकश्चेति षोडशानूपजाः स्मृताः ॥ ११ ॥

[13] उत्तमं विंशतिर्हस्ता मध्यमं षोडशान्तरम् ।
स्थानात् स्थानान्तरं कार्यं वृक्षाणां द्वादशावरम् ॥ १२ ॥

[14] अभ्यासजातास्तरवः संस्पृशन्तः परस्परम् ।
मिश्रैर्मूलैश्च न फलं सम्यग्यच्छन्ति पीडिताः ॥ १३ ॥

[15] शीतवातातपै रोगो जायते पाण्डुपत्रता ।
अवृद्धिश्च प्रवालानां शाखाशोषो रसस्रुतिः ॥ १४ ॥

[16] चिकित्सितमथैतेषां शस्त्रेणादौ विशोधनम् ।
विडङ्गघृतपङ्काक्तान् सेचयेत् क्षीरवारिणा ॥ १५ ॥

Bhaṭṭotpala has quoted Kāśyapa who cites intertwining of the roots (on account of close planting), and scratching by animals like elephants (to relieve itching) as further causes of disease.[17]

"In case of loss of fruit (fruit-drop disease) a decoction of Kulattha (Dolichos biflorus), green gram (Phaseolus mungo), black gram (Phaseolus radiatus), boiled in milk should be prepared and this should be sprayed over the fruit."[17]

The use of herbal solution with milk in control and treatment of disease is an astonishing feature in this chapter. The plant protection chemicals that are in use now-a-days are virulent systemic poisons which have caused much embarrassment and even deaths due to the systemic action on a wide variety of fauna including the humans. The use of simple methods of medication using herbs and readily available materials may be a more satisfactory solution for general use by the cultivators. The problem is worth serious study. The herbs used are free of any undesirable effects on human beings since many of them are useful for the treatment of human ailments also.

Nutrient Solutions and Tree Tonics

This topic is the most surprising one encountered in this chapter and shows the scientific and realistic attitude of the ancient Hindu savants. Although it looks rather bizarre at first sight, on reflection it is found to have some very sound scientific basis. It is worth a serious study not only by our plant sceintists and orchardists, but also by our municipal administrators. The method uses readily available materials to produce rich and effective plant nutrient slurries, and can help us to get rid of many obnoxious plant and animal remains that create problems in environmental sanitation in many townships. The commentator Bhaṭṭotpalācārya has gone to great length in explaining the weights and measures used for compounding the ingredients which shows that he also realised the civic importance of this practice.

"One Āḍhaka each of the powdered voidings of goat and sheep are taken together with powdered sesamum seed, fried barley grist in the amount of two āḍhakas and one prastha respectively, in one droṇa of water, placing in it one tulā of cow-meat. This mixture should be allowed to ferment over seven nights. If this fermented broth is fed to the trees and plants they will be bearing flowers and fruits continuously."[18]

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17. शाखाविटपपत्रैश्च छायया विहितैश्च ये ।
येऽपि पर्णफलैर्हीना रूक्षा पत्रैश्च पाण्डुरैः ॥
शीतोष्णवर्षवाताद्यैर्मूलैर्व्यामिश्रितैरपि ।
शाखिनां तु भवेद्रोगो द्विपानां लेखनेन च ॥
चिकित्सितेषु कर्तव्या ये च भूयः पुनर्नवाः ।
शोधयेत् प्रथमं शस्त्रैः प्रलेपं दापयेत् ततः ॥
कर्दमेन विडङ्गैश्च घृतमिश्रैश्च लेपयेत् ।
क्षीरतोयेन सेकः स्याद् रोहणं सर्वशाखिनाम् ॥ १४-१५ का ॥

18. फलनाशे कुलत्थैश्च माषैर्मुद्गैस्तिलैर्यवैः ।
शृतशीतपयस्सेकः फलपुष्पसमृद्धये ॥ १६ ॥

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In the commentary Bhaṭṭotpala gives a set of ślokas of undisclosed origin giving details of weights and measures. *Amarakośa* mentions three units of measurement (māna) namely, 'tulā' (weight), 'aṅguli' (length), and 'prastha' (bulk or volume) measures. In Bhaṭṭotpala's śloka the last line lays down that the liquid bulk measures are twice that of dry-goods' measure. That is to say, if one 'prastha' of water or oil be specified, one should measure out twice in dry goods 'prastha' measure. It is also worth noting that all the ingredients are measured out in bulk with the exception of cow-meat, which is specified by weight. It is worth noting that the rural agricultural population prefers to use bulk measures to weight measures whenever possible since measuring out in bulk is much easier and faster than using a pair of scales and set of weights. This method of quantity estimation involves very simple apparatus. At a pinch, even cupped palms may be used as measures. The traders, on the other hand, preferred to use a pair of scales since this was more specific than bulk measurement, as apart from variations due to specific gravity of materials, differences occur due to closeness of packing of the particles of the material and the tendency to heap up, and the manner in which the measure was filled affected the quantity. It may therefore be said that rural and agricultural population normally preferred bulk measures while the traders generally favoured the use of weight measures. We may take that the quantities specified in the verses are by bulk except in the case of meat.

Weight Measures

The basis of the Hindu weight measures was the grain of barley corn. This was also the basis of the weight measure used in olden times in all other civilised countries. According to the verses quoted by Bhaṭṭotpala,[19] the weight table may be developed as follows:—

Kṛṣṇala (seed of wild liquorice Abrus precatorius=3 Yavas (Barley grain)

Māṣala (Phaseolus radiatus—Māṣa)=5 Kṛṣṇalas, also 5 guñjas.

This is the Āḍhyamāṣa of *Amarakośa.* If we assume that Yava is the same as the English grain (0.0648 grams), the Māṣa becomes equal to 0.972 grams or nearly one gram metric.

16 Māṣas go to make up one Karṣa (62.208 grams)

4 Karṣas=1 Pala (248.832 grams)

In Varāhamihira it is stated that 4 palas go to make up a Kuḍava. This establishes the correspondence between the weight measure (pala) and the bulk measure ('kuḍava'). Such a correspondence exists in the metric system as one gram is accepted to be the mass of one millilitre of water at 4° Celsius scale of temperature.

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19. अविकाजशकृच्चूर्णस्याढके द्वे तिलाढके ।
सक्तुप्रस्थो जलद्रोणो गोमांसतुलया सह ॥ १८ का ॥
सप्तरात्रोषितैरेतैः सेकः कार्यो वनस्पतेः ।
वल्लीगुल्मलतानां च फलपुष्पाय सर्वदा ॥ १८ का ॥

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This sentence appears to be merely to denote that such a correspondence exists between the unit of bulk measure, the kuḍava and the unit of weight pala. Actually there is a sub-multiple of the 'kuḍava' called the 'Kuñca' or 'Nikuñcaka' which is a quarter of a Kuḍava. Now, to continue the weights table we may proceed as follows (assuming that kuḍava is 250 millilitres or gram making pala=62.5 grams):

Tulā=100 Palas. (6.25 Kilos metric)
Bhāra=20 Tulās. (125 Kilos)
Ācita=10 Bhāras (1250 Kilos)

It is said in *Amara* that Ācita is the same as Śākaṭa or the cart-load. Ācita actually means a collection or a heap, and the merchants in those days must have collected an Ācita of goods or mearchandise and contracted for their carriage in goods carrying carts or wagons.[20]

Bulk Measures

The unit of bulk measure was obviously the Kuḍava from which the Madras measure called the 'Kuḍata' is derived and this liquid measure is equal to ½ litre (See page xlv. Volume I of Dr. Nadkarni's *Indian Materia Medica.* The definition of Kuḍava is given in the Sanskrit —English Dictionary by Sir Monier-Williams (1872 edition page 234 Column 1), as follows:—

> "A measure of grain, wood, iron etc., the fourth part of a prastha, described by some as a vessel four fingers wide and as many deep and containing twelve prakṛtis or handfuls; it is also said to contain 13½ cubic Aṅgulas; or to be a finger and half deep, and three fingers each of length and breadth; in medicine it is equal to two prakṛtis or thirty-two tolakas."

The word 'Kuḍava' probably derives from the root 'Kuḍ' meaning 'to heap' 'to plunge' or 'to be immersed'. The various meanings of the root are suggestive of the manner of using a measure (dipping and pouring out, heaping in and pouring out). Obviously there were many Kuḍava measures in use. The 4-aṅgula Kuḍava has a cubic volume of 442.5 millilitres, nearing the Madras Kuḍata measure. The 1½ finger Kuḍata contains 93 Millilitres, and approximates to the small fluid or bulk measure used in South Kanara and Kerala. If the wet Kuḍata be assumed to be

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[20] मानं तुलाङ्गुलिप्रस्थैर्गुञ्जाः पञ्चाद्यमाषकः ।
ते षोडशाक्षः कर्षोऽस्त्री पलं कर्षचतुष्टयम् ॥
सुवर्णविस्तौ हेम्नोऽक्षे कुरुविस्तस्तु तत्पले ।
तुला स्त्रियां पलशतं भारः स्याद्विंशतिस्तुलाः ॥
आचितो दश भाराः स्युः शाकटो भार आचितः ।
कार्षापणः कार्षिकः स्यात् कार्षिके ताम्रिके पणः ॥
अस्त्रियामाढकद्रोणौ खारी वाहो निकुञ्चकः ।
कुडवः प्रस्थ इत्याद्याः परिमाणार्थकाः पृथक् ॥
Amara, II, Vaiśya, 85-9.

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equal to the Madras Kuḍata of 500 Millilitres, the dry Kuḍata would be 250 Millilitres.[21] On this basis the bulk measure table may be completed as follows:

Name of the measure	*Metric equivalents*	
	Dry	*Wet*
Kuñca or Nikuñca	1/16th Ltr.	1/8th. Ltr.
Kuḍava=4 Kuñcas	0.250 Ltr.	0.250 Ltr.
Prastha=4 Kuḍavas	1 Ltr.	2 Ltrs.
Āḍhaka=4 Prasthas	4 Ltrs.	8 Ltrs.
Droṇa=4 Āḍhakas	16 Ltrs.	32 Ltrs.
Mānika=4 Droṇas	64 Ltrs.	128 Ltrs.
Khārī=4 Mānikas	256 Ltrs.	512 Ltrs.

The *Amarakośa* mentions Kumbha and Vāha which respectively are 20 Droṇas (640 Ltrs.) and 200 Droṇas respectively. These measures were obviously used in assessment of irrigation duties.

Now the composition of the tree-tonic may be laid down in metric measures.

Powdered goat and sheepdung 1 Āḍhaka each	8 Ltrs.
Sesame seed 1 Āḍhaka	4 Ltrs.
Barley groats or grist (fried and ground, 1 Prastha)	1 Litre.
Cow-meat 1 Tulā	6.25 Kilos.
Water 1 Droṇa	32.00 litres.

The cow-meat mentioned is most certainly the carrion meat that was unfit for human consumption. Since the other slaughtered meats were in demand for human consumption, they would not have been available cheaply for use in the above manner. The mention of cow-meat for such use would lend support to the presumption that cows were not slaughtered for food. Nor were the carcasses allowed to rot in the open and vitiate the atmosphere creating unsanitary conditions. Their use in plant nutrients ensured that large quantitites of carrion meat could be disposed off effectively in this manner and contribute to agricultural production. The fact that the mixture prepared as above was allowed to ferment for over 7 nights is interesting. The conditions under which the above mixture ferments is semi-anaerobic, and under therse circumstances the nutrient value of the mixture upgrades substantially, by the pre-digestion of proteins in grain and meat which converts the nitrogen in the proteins into available ammoniacal form. The following paragraph from "I.C.A.R. Hand-book of Manures and Fertilisers" is of interest.

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[21] त्रियवं कृष्णलं विन्द्यान्माषलः पञ्चकृष्णलः ।
ते स्युर्द्वादश लक्षाख्यं सुवर्णमथ षोडश ॥
पञ्चलक्षैश्चतुर्भिस्तु सुवर्णैर्निष्क उच्यते ।
चतुष्पलोऽथ कुडवः प्रस्थः स्यात् तच्चतुष्टयम् ॥
आढकस्तु चतुष्प्रस्थो द्रोणस्तु चतुराढकः ।
मानिका तु चतुर्द्रोणा खारी स्यात्तच्चतुष्टयम् ॥
तुलापलशतं ज्ञेयं भारः स्याद्विंशतिस्तुलाः ।
शुष्कद्रव्येषु सङ्ख्येयं चार्द्रेषु द्विगुणा भवेत् ॥
Q. by Utpala under verse 18.

'Under partially anaerobic conditions, there is an accumulation of intermediate products of decomposition. The various organic acids so liberated combine with ammonia to form ammonium salts preventing the loss of ammonia by volatalisation. The acids also lower the pH value of the manure and make it less alkaline. There is nitrate formation under such conditions. The loss of organic matter is considerably reduced. Hence, there is greater conservation of organic matter and nitrogen, and greater portion of the manure than under aerobic decomposition "[22].

From the above it would seem that the method of preparation of manures advocated in Vṛkṣāyurveda of Varāhamihira would be more economical and effective than the aerobic composting methods advocated by the scientists in the recent past such as the Indore method and the Bangalore method (*op. cit.* Pp. 67,72,74), and is much faster. Of course this method does not utilise the litter stalk leaves etc. which can be used more effectively in the Indore and Bangalore methods. But materials like spoilt meat and grain can be converted into plant nutrient mixtures within a very short time. This should be of particular value during emergencies when the production from a plant has to be sustained or accelerated to meet heavy seasonal demands such as during festivals, cultural and political pageants when there is an unusually heavy demand for flowers, as well as for certain fruits.

Before we conclude this topic it is worth mentioning that we have now better knowledge of the composting and biological decomposition processes and the completely anaerobic process of fermentation of animal and plant wastes which forms the basis of the bio-gas plant[23] (Cowdung gas plant) and has been studied quite extensively by various workers, particularly in the Indian Agricultural Research Institute in New Delhi by Patel, Acarya and others, who have demonstrated the multilateral benefits of this process. The main point that might be noted is that the nitrogen content in cow-dung is raised from 0.30 (0.26 in buffalo-dung) to 2.0 to 2.4 in digested slurry after digestion in the plant during which period some 1 to 1.5 cubic feet of rich fuel gas is also produced containing methane, which can be used as a domestic fuel. Even after drying the slurry retains 1.8% of nitrogen which is more than six times that contained in fresh dung. But there is a loss of almost the whole of the ammonia content during the drying of the slurry. The ancient Hindu process achieves an upgrading of the nutrient quality of the solution in a shorter time but without the advantage of getting the benefit of a fuel gas. The present writer has seen an installation of the bio-gas plant in tne Kora Gramodyoga Kendra at Borivili, a satellite suburb of Bombay on the Western Railways. The plant is also used to digest the carrion meat from the buffalo cadavers and the digested slurry resembles the digested cow- or buffalo-dung in every way. One great advantage of the process is that almost all the pathogenic organisms in meat etc. are destroyed in the process and there is almost complete mitigation of fly nuisance that is usually associated with most of the slaying houses or slaughter houses. The administration

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22. *Handbook of Manures and Fertilisers*, ICAR, Pp. 61-62.
23. *Op. cit.* Pp. 84-86.

of the colony earns a handsome profit from the sale of the digested slurry as high grade manure to the agriculturists and horiticulturists round the area. Public health and municipal administrations might note this.

The process described by the ancient Hindus does not involve any complicated apparatus and the most attractive feature is the use of waste products such as grain and carrion meat. By adopting the practice, the municipalities in the country can dispose of the dead cattle and animals that many times obnoxiously clutter up the streets in our towns and villages in a hygienic and inoffensive manner and at the same time helping to supply high grade manure to the cultivators, orchardists and market-gardeners, thereby earning for the town administration a gainful return. The digested slurry resulting from the process can be supplied to the customers conveniently in wheeled sanitary carts.

The process may be advantageously studied in all its implications by the plant scientists and public health engineers. The existing sewage disposal plants in many townships can be easily adapted to take advantage of the process.

Kāśyapa's verse on the subject[24] uses essentially the same formulation with half the quantity of goat and sheep-dung powder. The purpose of the sheep and cow-dung powder seems to be to provide a bacterial inoculum necessary for the process. It is also worth noting that dung of goats and sheep has higher nitrogen content to start with than that of buffalo- or cow-dung.[24]

Techniques of Seed Germination

Another equally interesting topic is the various methods of sprouting seeds that are normally difficult to germinate. An elaborate technique is described for seeds of Ferronia elephantum (the wood-apple or the elephant apple). The general process for treating the seeds is described thus:

"The seeds must be soaked daily in milk handling them with hands smeared with ghee for ten days, after which they must be coated with cow-dung paste and finally fumigating them with smoke from burning pieces of deer-flesh and boar-flesh, after placing them in a pot."[25]

" The seeds should be sown in earth that has been mixed with flesh trimmings and boar fat and treated by sowing sesamum seeds as explained in verse 3. The sown seeds should be watered with a mixture of milk and water, when they will germinate bearing flower-buds, and will become heavy with flowers and fruits."[26]

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[24] अजाविकानां द्वौ प्रस्थौ सकृच्चूर्णं च कारयेत् ।
तिलानामाढकं दद्यात् सक्तूनां प्रस्थमेव च ॥
गोमांसशतमेकं स्याद् द्वे सार्धे सलिलस्य च ।
सप्ताहमुषितैरेतैः सेकं दद्याद्वनस्पतेः ॥
स भवेत फलपुष्पैश्च पत्रैश्चाङ्कुरितैर्वृतः ॥

[25] वासराणि दश दुग्धभावितं बीजमाज्ययुतहस्तभावितम् ।
गोमयेन बहुशो विरूक्षितं क्रौडमार्गपिशितैश्च धूपितम् ॥ १९ ॥

The use of the hyperbole is obviously inteded to impress upon the reader the supposed efficacy of the method.

The next verse describes a method that purports the guarantee of the sprouting of Tintiḍi (Tamarindus indica=Tamarind), which as Bhaṭṭotpala says in his commentary, is a very hard seed and apparently a very shy germinator.

" Even tamarind can be sprouted if a mixture of rice, sesame, black gram, barley grist and stale carrion meat be used and continuously fumigated with burning pieces of turmeric root. "[26a]

Ferronia Seeds

Varāhamihira in five verses describes the process of germinating the seeds of Ferronia elephantum. Dr. Nadkarni's *Indian Materia Medica* gives a number of its medicinal uses. The fruit is crushed and made into relishes with sugar or honey. It must have been much valued in those days to have warranted such elaborate germination methods.

" The principles of germinating Kapittha seeds is as follows:- A medicinal decoction is prepared by boiling in milk roots of Asphota (Calotropis gigantea, Echites dichotoma, Bauhinia variegata), Dhātrī (Emblica officinaliso), Dhava (Grislea tomentosa—Woodfordia floribunda) and Vāsika (Adhatoda vasika=Malabar nut). Whole plants with foliage of Vetasa (Calamus rotang), Sūryaballī (Cleome viscosa=Wild dog mustard) ; Śyāmā (Icchnocarpus frutoscens; Hemedesmus anantamul); Atimukta (Dalbergia ougeinensis, Jasminum pubens) ; then it is cooled and taken."[27]

"The ferronia seeds should be placed in the above medicated liquor daily for a duration of 100 seconds (handclaps or beats) and dried in the sun, repeating the (daily) process for the period of one month, after which they will be ready for sowing. "[28]

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[26] मांससूकरवसासमन्वितं रोपितं च परिकर्मितावनौ ।
क्षीरसंयुतजलावसेचितं जायते कुसुमयुक्तमेव तत् ॥ २० ॥

[26a] तिंतिडीत्यपि करोति वल्लरीं व्रीहिमाषतिलचूर्णसक्तुभिः ।
पूतिमांससहितैश्च सेचिता धूपिता च सततं हरिद्रया ॥ २१ ॥

[27] कपित्थवल्लीकरणाय मूलान्यास्फोतधात्रीधववासिकानाम् ।
पलाशिनी वेतससूर्यवल्ली श्यामातिमुक्तैः सहिताष्टमूली ॥ २२ ॥

[28] क्षीरे शृते चाप्यनया सुशीते तालाशतं स्थाप्य कपित्थबीजम् ।
दिने दिने शोषितमर्कपादैर्मासं विधिस्त्वेष ततोऽधिरोप्यम् ॥ २३ ॥

"A pit should be dug a cubit wide and two cubits deep, and filled with a mixture of milk and water and allowed to dry out, after which a fire should be built in it, burning it thoroughly, after which it should be smeared on the inside with a mixture of honey, ghee, and wood ashes."[29]

"Thereafter, a mixture of powdered black gram, green gram, sesamum, and barley should be obtained and the pit filled up with soil and the lentil grain powder, in the following manner : A layer of soil 3 inches thick (4 Aṅgulas) should be placed in the pit and lentil grain mixture spread on it consolidating it by beating, sprinkling with water containing pieces of flesh and fish. The process is repeated until the entire pit is filled up and the earth-filling beaten hard sprinkling it with cold aqueous infusion of fish and flesh."[30]

"The treated seeds are sown at a depth of 3 inches (4 Aṅgulas) loosening the soil as required to the proper depth, and watered with the meat and fish infusion; whence the seeds will readily germinate covering the entire basin with vigorous shoots in the most astonishing manner."[31]

The elaborate process described raises several interesting points and some problems. The names of the herbs mentioned above are somewhat in doubt and no directions have been given regarding the proportions in which the various ingredients are to be taken, how long the boiling should be continued etc. Why so much of attention should be bestowed on this particular tree is not very clear. To what other seeds can the process be extended and what is the action involved as a result of the various steps described? In the case of Asphota, the term applies to several plants, named in the brackets. The word Śyāmā also applies to Ipomea turpethum (Indian Jalap), Ocimum sanctum and many other plants. The word Atimukta also creates some difficulties. These questions can be solved only through systematic experimentation.

Further Seed Treatment and Sprouting methods

"Seeds are treated hundred times with the juice or pulp of Angola fruits (Alangium hexapetalum=Sage-leaved alangium), or in the juice of Śleṣmātaka (Cordia latifolia=Sebastian plum); after which being sown in a soil watered with melted hailstones, they will sprout immediately and their branches will become heavy with fruits and flowers."[32]

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[29] हस्तायतं तद्विगुणं गभीरं खात्वावटं प्रोक्तजलावपूर्णम् ।
शुष्कं प्रदग्धं मधुसर्पिषा तत् प्रलेपयेद् भस्मसमन्वितानाम् ॥ २४ ॥

[30] चूर्णीकृतैर्माषतिलैर्यवैश्च प्रपूरयेन्मृत्तिकयान्तरस्तैः ।
मत्स्यामिषाम्भस्सहितं च हन्याद्यावद्घनत्वं समुपागतं तत् ॥ २५ ॥

[31] उप्तं च बीजं चतुरङ्गुलाधो मत्स्याम्भसा मांसजलैश्च सिक्तम् ।
वल्लीभवत्याशु शुभप्रवाला विस्मापनी मण्डपमावृणोति ॥ २६ ॥

The word "a hundred times" may just mean "several times". The seeds are to be treated perhaps by steeping briefly in the pulp of the fruits indicated and dried, repeating the process several times. The treatment with water from melted hailstones may mean just strongly chilled water. The shock treatment perhaps helps in breaking down the dormancy of the seeds.

"The fruits of Śleṣmātaka tree are decorticated carefully and treated with the pulp of Angola furits seven times, drying them in the shade each time, and they should be placed in a heap of powdered buffalo-dung on soil wetted with water from melted hailstones, whence they will become fruitful (effective) within a day."[33]

The word "phalakāriṇī" should be interpreted as meaning that the process of sprouting will become effective within a day, or that the treatment will ensure sprouting within a day, and not that the sprouted plants will start bearing fruits within a day as stated by some translators. The verses on germination etc. are crowded with hyperboles, which may be only rhetorical for emphasisng the effectiveness of the treatment and should not be taken too literally.

Astericisms favourable to planting of trees and their propagation

"The divines or the savants opine that the trees and plants should be planted or sown when the moon is passing through favourable lunar mansions which are— the three Uttaras (Uttara, Uttarāṣāḍha, Uttarabhādra); and Rohiṇi known as the dhruvās or the end stars; Anurādhā, Citrā, Mṛgaśīrṣa, Revatī, known as the mild astericisms; and Mūla, Viśākha, Puṣya, Śravaṇa, Aśvinī, Hasta[34].

The moon is the nearest celestial body to the earth and its influence is felt in a visible manner as the pull of gravitation which raises the tides. Even the solid ground surface is shown to rise and fall by as much as 6" through delicate instru-

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32. शतशोऽङ्कोलसम्भूतफलकल्केन भावितम् ।
एतत्तैलेन वा वीजं श्लेष्मातकफलेन वा ॥ २७ ॥
वापितं करकोन्मिश्रमृदि तत्क्षणजन्मकम् ।
फलभारान्विता शाखा भवतीति किमद्भुतम् ॥ २८ ॥

33. श्लेष्मातकस्य बीजानि निष्कुलीकृत्य भावयेत् प्राज्ञः ।
अङ्कोलविज्जलाद्भिश्छायायां सप्तकृत्वैवम् ॥ २९ ॥
माहिषगोमयघृष्टान्यस्य करीषे च तानि निक्षिप्य ।
करकाजलमृद्योगे न्युप्तान्यह्ना फलकराणि ॥ ३० ॥

34. ध्रुवमृदुमूलविशाखा गुरुभं श्रवणस्तथाश्विनी हस्तः ।
उक्तानि दिव्यदृग्भिः पादपसंरोपणे भानि ॥ ३१ ॥

ments. It therefore goes without saying that these forces should be exerting influence on all material constituents of the earth, which consideration lends some support to the theory of astral or planetary influences. Scientists have been toying with these theories now and then but have not come to any definite conclusion. In this connection it is worth recalling that Dr. Rudolph Steiner, the leader of a movement called "Anthroposophy" had experimented extensively on the subject. We can only say that the last word has not been said on the subject. The orbiting space laboratories where gravity may be controlled, may reveal some of the secrets in course of time, after the behaviour of plants grown in such environments have been studied. For the time being, the best we can do is to keep an open mind.

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CONTRIBUTION OF VEDIC AND POST-VEDIC INDIAN SCHOLARS TO SCIENTIFIC KNOWLEDGE

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India is very fortunate in its literature of ancient times that has been preserved correctly. Unlike Babylonians, the Aryans did not leave behind any tablets etc. except some pottery. But they left the most important and ancient encyclopaedia of all kinds of knowledge of those times, namely the *Ṛgveda*. In the Vedic literature especially, the verses on the heavenly bodies are the most fascinating and provide a lot of information about the celestial observations of the ancients. The record of this knowledge of old times is very important, being the oldest preserved record not available anywhere else, and more informative than the cuneiform tablets of Babylonian civilization. The ancient knowledge of the Vedas continued to develop in the later Sanskrit literature upto about the 12th century A.D. In spite of many important developments in the realm of science in Sanskrit, due credit has not been given to the Vedic or post-Vedic discoveries. Neuguebauer, Kugler and many other Western historians of science give all the credit for developments to Hellenistic Sciences and to Babylon, Greece etc. The original contributions by Indian scholars have to be drawn attention to.

Astronomy

(1) As has already been mentioned, the *Ṛgveda*-verses on heavenly bodies are the most interesting. The naming of days against Nakṣatras shows the knowledge of the lunar Zodiac at the time of the oldest strata of *Ṛgveda*. Dr. Biot's arguments for assigning the origin of this knowledge to Babylon are in vain as we do not get any information about Nakṣatras in tablets, and the close connection of Vedic deities with the Nakṣatras and their meaningful names in Sanskrit indicate the Vedic origin of this knowledge. The list is complete in the *Taittirīya Samhitā* and the *Atharva Veda*. The Nakṣatra-system spread to China, Japan and Arabia from India.

(2) Tithi is defined in *Aitareya Brāhmaṇa* and has no equivalent in Babylonian or other civilizations. However, it is suspected that the word "Tithi" in Greek has connection with this very time-reckoning. The lunar calendar probably started in pre-Vedic times.

(3) Karaṇa is defined as half of Tithi. This was used by the Arabs also. Alberuni in his *Indica* compares the Arabic and Indian methods of calculating Karaṇas. Some of the names of Karaṇas seem to have an Arabic origin. The

subject is under investigation. Recently the mystery has been resolved and the results have been sent to *Historia Mathematica* of Toronto University in Canada.

(4) The Yogas developed in India starting from two at the time of *Vedāṅga Jyotiṣa*[1] to the total number 27 in the later theoretical Astronomy. Yoga is the sum of celestial longitudes of Sun and Moon. This quantity is useful for computations of equality of declinations. The validity of the current traditional school on calculations of Yogas is not right. The method has been completely discussed by some scholars of Drik School.

(5) The earliest mention about Kṛttikās is in the *Śatapatha Brāhmaṇa* (2.1.2) where these are mentioned as rising in the east. The Kṛttikā Calendar of old Arabs (just like the Egyptian star clock) might have derived inspiration from this statement, whatever may be the date of the spread of the Nakṣatra system to the Arabs. For readers interested in the Calender of Plaiedes of old Arabs J. Henninger's work is worth referring[2]. It is to be pointed out that at the time of the use of the Stonehenge structures of Salisbary planes of England Kṛttikās were not on Equator but were 5° to the north.

(6) The earliest reference to Orion in *Old Testament* is in Amos (760 B.C.). But there is no doubt that the Orion was referred to in *Ṛgveda* in its oldest strata (See *Orion* by Tilak).

(7) As the Lunar Zodiac is expected to be first in Astronomical knowledge the Greek definition of Ecliptic and Rāśis (signs) came very late in the history of Astronomy. It is believed that the ancients used to be at one place where they had developed the notion of Lunar Zodiac (as also remarked by Max Muller on the basis of similarity in the names of Moon in German, Sanskrit and Greek). This shows the remote antiquity of Ṛgvedic oral traditional knowledge. We will give some more arguments in favour of this hypothesis.

(8) The first mention about Jupiter is in Vāmadeva's *Sūkta* in *Ṛgveda*, 1st Maṇḍala and *Tāṇḍya Brāhmaṇa*[3], where according to Fleet, Tilak, Jacobi, Dixit etc., Jupiter is mentioned as confronted with *Tiṣya* (*Puṣya*). This event could not happen in the period between 4650 B.C. upto now. This shows the remote antiquity of the Vedic traditional system and it is emphasised that Ṛṣi Vāmadeva should be given the credit of discovering Jupiter. One should not be astonished at this remote antiquity of knowledge about Jupiter and probably of a Venus also as shown by Tilak but doubtful due to the very vague meaning of the relevant verses. It may be noted that in Kohistan caves planetary positions of 10000 B.C. are found engraved. Near equinoctial positions of the Sun, the heliocentric rising, setting of Sirius (as pointed out by Tilak) and of Canopus (as pointed out by Dr. Kern) are

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1. *Vedāṅga Jyotiṣa*. ed. by Dr. R. Shama Sastry.
2. J. Henninger, *Uber sturnkunde and sturnkult nord und Zetratarabian entologie*, 1954. 82-117.
3. *Tāṇḍya Brāhmaṇa*- बृहस्पतिः प्रथमं जायमानः...... तिष्यं नक्षत्रम् अभिसम्बभूव ।

contemporary events and it is not surprising that these interpretations of the respective verses might be right as similar traditions are traceable in Star Clock-lists of Coptic or other civilizations. In connection with such heliocentric risings in Avesta also, the remarks of Cyril Fagan (who is considered to be the father of Sidereal School in the West) are worth noticing. It is to be pointed out that some similar heliocentric rising for Falmhault etc. are reported in Avesta also, and here it is to be pointed out that the Egyptians at the time of usage of the Star-lists were not aware of the cardinal points, as we find the positions of stars reported by pointing out the fact that the star is behind that tree or that corner of building, on left shoulder or, on right shoulder etc. The Vedic tradition was always for using the cardinal points and this was the best method of recording the positions of stars before the development of the notion of ecliptic and lunar Zodiac. The tradition is clear from कृत्तिकास्वादधीत नैता ह वै पूर्वतश्चयवन्ते (*Śatapatha* 2.1.2). Thus it was quite normal for Aryans to associate the heliocentric setting or rising of stars with the positions of Sun with reference to the cardinal points. The method of determination of these points is quite clear from the study of the Ṛgvedic *Aitareya Brāhmaṇa* and *Śulba-sūtras.* It is quite easy to find solstice points by decreasing the Virāj days for stationary Sun (which was 5 days, then reduced to 3 days) and the determination of equinoctial points is also easier. Note that even in quite old times the cardinal points could be determined, as is evident from the Stonehenge structures and the Callanish structures. The Callanish structures are believed to belong to the Stone age of man. Chinese claim gnomon experiments about 4000 B.C. or even earlier. It is noteworthy that Aryans gave the positions of planets (Sun, Jupiter and also Moon) with reference to lunar Zodiac, and of stars with reference to the cardinal points (directional as well as of Sun).

Many cardinal positions of Sun with reference to stars and also of moon are given in Vedic literature. These provide quite old dates for the literature. These texts and Hittite clay tablets have proved Max Muller's hypothesis to be wrong.

Precession was known to Indians as zero point of the Zodiac was moved but without giving the velocity. *Ad hoc* changes were done from Orion to Plaiedes, Bharaṇi (in *Vedāṅga Jyotiṣa* periods) and then to Aśvinī. But the verbal statement about precession is found in Hipparcus only.

The idea of Lunar months is quite old and intercalation was done in all ancient civilizations. *Ṛgveda* calls Moon मासकृत् and has the old reports of *ad hoc* intercalation. In German and in Greek also Moon is said to be मासकृत्. Later Sun is said to be मासकृत् which shows the development of the notion of Solar Calendar.

Also the *Maitrāyaṇīya Brāhmaṇa* Upanishad reports the Dhruva (the Pole star-Draconis) on the basis of which the Hindu system of marriage tradition was started and according to which the bride and groom have to see the Pole Star

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and promise to be Dhruva (faithful) to one another. The Draconis was Pole Star at that time. This is also reported by the Chinese and is also preserved in orientations of pyramid-tunnels of Egypt. There was no stationary Pole Star since then upto now, and even in future Vega star (अभिजित्) will become Pole Star after many thousands of years.

Romaka and *Pauliśa Siddhāntas* are believed to be of Hellenistic origin. But Brahmagupta refers *Romaka Siddhānta* to Śrīṣeṇa; Pauliśa may be the corrupt form of "पुलस्त्य". The only thing which was taken as a hint from Hellenistic sciences was the epicycle-theory of Appolonius of Perga.

There was independent development of Indian Calendar at earlier stages. Its features are very much common to the old Hebrew Calendar. It has now developed to be the most scientific Luni-Solar Calendar of the world. It incorporates in it intercalary and decayed months, which are a must for a scientific Luni-Solar calendar.

Vaṭesvara, the author of *Vaṭeśvara-Siddhānta* of about 8th or 9th century A.D., was the first to give Velāntara-Samskāra (the equation of time).

About the inequalities of Moon the works of Muñja (8th A.D.), Śrīpati and Bhāskarācārya (12th cent. A.D.) are worth mentioning before the advent of perturbation theory, which developed quite later after the mathematical formation of the law of gravitation. These Indian astronomers gave erection, variation, annual variation and first equation of centre for the longitude of the Moon. The results from the formulas are correct up to two. But unfortunately these formulas were not adopted in practice by the Almanac-makers of India.

The *Jaimini Sūtras* are very important in this connection. Some work is continued in this direction. This will throw light on the contribution of India.

Medicine

The system of medicine started developing in the *Ṛgveda*. The *Atharva Veda* has Āyurveda as its supplement. *Yajurvedīya Śatapatha Brāhmaṇa* enumerates the bones of human skeleton. Greek historians Dioscorides and Pliny mention about the imported Indian drugs and Indian Physicians for Alexander. Hellenistic historians Nearchus and Magasthenes praised the imported medicines from India. This science developed in India before the contribution of the famous physician Hippocrates (400 B.C.).

Suśruta is given the credit of being the father of surgery. He gave in his Samhitā, over one hundred instruments. He gave the first *Materia Medica* (Encyclopaedia of Medicine). Later Kauṭalya discussed the classes of doctors, home-surgeons, nurses etc. *Hastyāyurveda* is the oldest veterinary science

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in India. Also we find *Aśva-Āyurveda* and also a medicinal system for plants etc. In about 1st A.D. Caraka recognised epidemics for the first time.

Nāgārjuna is to be given the credit of inventing the process of distillation and other processes. He used the distillation to get vital alkalis and acids.

From 500 B.C. to about 500 A.D. Nalanda University continued work and training on Rhinoplasty for repairing nose, ear, eyes etc.

Technology

Indians know bleaching, extracting medicines from Copper, Mercury, Lead, Tin, Zinc etc. They were good in metallurgy. In Delhi stands the iron-pillar unaffected for about 1500 years. The Arabs imported Indian swords and cavalry-items from India. The steel was first manufactured in India. For Egyptian mummies, Indian muslins were used. The Biblical Kings used decorative items from India. It is to be noted that the Hebrew words for ivory, cotton cloth, sandalwood etc. are either from Tamil or Sanskrit. The Indian temples and old buildings show the development of architecture in olden times. Vāstu-Śāstra is an important branch of Sanskrit literature and one finds the application of all the branches of mathematics developed in the Vāstu-Śāstra. Even the theory of Numbers was used. For preparing buildings the direction was determined using Astronomical gnomon experiments although it is clear from the Vaiśeṣika Darśana that the magnet's force was known but not its directional property. The orientation of buildings was decided in such a way that Sun-light may be available at appropriate times. *Vasiṣṭha Samhitā*, *Samarāṅgaṇa Sūtradhāra* etc. are important texts on these subjects. *Yuktikalpataru* deals with ship-building. Indian were the pioneers in this field.

About the rain and meteorology we find literature in Sanskrit and it is very important to pinpoint two facts here:

(1) In प्रवर्षणा-theory there is a method for calculating the height of a cloud knowing the time taken by thunder-sound to reach the observer. It is found that this gives the velocity of sound equal to almost its value in modern science.[4]

(2) In प्रवर्षणा-मिति it can be proved that Indians used rain-guage which took care upto 15 cm. only.[5]

There are also found references to Vimānas or aerial vehicles.[6] Books on Metallurgy existed. They are mostly lost.

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[4] Sen Gupta, *Vedic Antiquity*.

[5] Dr. Mohammad I. Khan, *Indian News*, Clarion State College, Clarion. P.A., U.SA., April 24, 1970.

[6] *Bṛhadvimāna Śāstra*, (Part of Bhāradvāja muni's *Tantrasarvasva*).

Mathematics

Mathematics has its germs in *Ṛgveda,* which resulted in the form of *Vedāṅga Jyotiṣa* methods of calculating the syzygies. The 1st indeterminate equation of 1st degree is found solved in Ārṣa-Jyotiṣa.[7] This solution is earlier than the attempt of Babylonians in this direction as depicted in the tablets. Jain works like *Sūrya* and *Candra Prajñaptis* are also worth mentioning.

The *Sulba Sūtras* give the trial solutions of some of the so-called "Pellian equations." The integral solutions are given for the problems and also for the so-called Pythagoras equation. The *Sulba Sūtras* show development of geometry. Dr. Neuguebauer tries to show the connection of *Vedāṅga Jyotiṣa* and *Sulba Sūtras* with the Babylonian civilizations. It is worthwhile to discuss here this subject.

The ratio of maximum to minimum length of the day is given to be 3:2 in Babylonian tablets. And the *Vedāṅga Jyotiṣa* gives the formula for the length of the day—

$$\text{Day} = 12 \pm \frac{2(183-n)}{16} \quad \text{Muhūrtas}$$

where $n=$ the no. of days lapsed after a solstice' day and 1 muhūrta $=2$ ghaṭis$=$ 48 minutes. This also gives the ratio 3:2 of maximum to minimum as pointed out by Nauguebauer. But it has been shown by Sri N.C. Lahiri that considering the errors of *Jala-ghaṭīs* (clepsydra) used in the Babylonian and *Vedāṅga Jyotiṣa* period and also considering the corrections due to refraction etc.[8] this very ratio amounts to the value for Gandhara also. But we may note here that these tablets do not give the formula in this form and these belong to the Celeucidian period as evidenced by Denmark Book IV which states that the *Vedāṅga Jyotiṣa* and *Sulba-Sūtras* had reached those places in the West[9]. The date of *Vedāṅga Jyotiṣa* is determined from **"प्रपद्येते श्रविष्ठादौ सूर्याचन्द्रमसावुदक्"** which shows its compilation-date as c. 1400-1500 B.C. which is earlier than the tablets of Celucidian period.

About the *Sulba-Sūtra,* connection is hinted at the solution of the so-called Pythagoras equation, again in the tablets of Celucidian period. Also it may be pointed out that *Sulba Sūtras* give the solution of the so-called Pellian equations also, which are not available in the tablets. And it is well known that Pythagoras came to India to study with the Brahmins. Appollonius, the ancient Greek astronomer, mentions that Pythagoras went to India and was taught by Brahmins. Dr. Hopkins says: "Before the 6th century B.C. all these religious and philosophical ideas (of Pythagoras) were current in India."[10] We may point out here that Pythagoras studied medicine also from India and used Indian drugs. He also borrowed knowledge of ecliptic etc. from the Greeks. The *Sulba Sūtras* give practical geometry and it is thought worthwhile that the credit of Pythagoras equation should go to Indians.

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[7] Dr. S. D. Sharma, Lectures in Mallorca Island (Spain).

[8] N. C. Lahiri, "*Report of Calendar Reform Committee.*"

[9] O. Neuguebauer, *Exact Sciences in Antiquity, Astronomical Cuneiform Tablets* etc.

[10] Dr. Mohammad I Khan, *India News,* April, 1970.

There was some connection with the literature of Appollonius of Perga at the time of compilation of *Sūryasiddhānta* (S.S.). The polar longitude and latitudes of stars in S.S. are the same as in the work by Appollonius. But it may be pointed out here that Ptolemic School did not come to India for a very long time (upto the time Jayasingh when *Siddhānta-samrāṭ* was written) and even S.S. has *Mandaparidhis* etc. different from those of Appollonius which shows the acceptance through original approach.

In about 200 B.C. Piṅgala developed the method of framing Chandas, which resulted in the development of theory of permutation and combination.

While Pythagoras was the first one to teach some of his students that the earth is a planet and revolves around the sun (later same idea with Aristarchus in the 3rd century A.D.) Āryabhaṭa was the first one to point out the rotational motion of the earth. These ideas did develop later in the past but were not followed over a long period in the History of Astronomy.

Zero was introduced by Indians and adopted by Arabs and Western Europeans later. Decimal system also developed in India. Āryabahaṭa gives Algebraic method but some Algebraic equations seem to have been solved in Babylonian tablets. In fact the operations with algebraic symbols appear quite late in the work of Śrī Brahmagupta (580-660 A.D.) whose work was translated into Arabic. The Arabs borrowed their knowledge from Greece and India and propagated to Western Europe through Sicily and Spain. Al-Khwarazimi (780-850) A.D.) called Mathematics "Ilme Hindi". His book based on Indian Mathematics was translated into Latin and remained as the principal text upto about 12th century A.D. A Greek monk Planudes called his book "Indian Arithmetic". It may be noted that the word cipher is from śūnya and Jyab from Jīva (sine).

In the 7th century A.D. the Christian monk Astronomer Severn Seboukt talks of India very highly. Brahmagupta's work was translated into Arabic by Al-Farabi and formed the basis of scientific knowledge of the great ancient Arabic scientist Al-Khwarazimi. Then Arin (Ujjain) was used as Greenwich.

Jain literature deals with series and in the 14th century Nārāyaṇa Paṇḍita and his followers later on continued work in this direction. In about 535 A.D. Śaṅkara Varma of Kerala in the Sabhā of Śrī Rāma Varma's brother Udaya Varma gave the value of π correct upto 18 decimals using the infinite series developed in the treatment.[11]

$$\pi = \frac{\sqrt{12}}{1} - \frac{\sqrt{12}}{3\times3} + \frac{\sqrt{12}}{3^2\times5} - \frac{\sqrt{12}}{3^3\times7} + \frac{\sqrt{12}}{3^4\times9} - + \ldots\ldots\ldots$$

Here the Kaṭapayādi system is followed. The text is—

व्वासघ्नेऽर्कपदे कृतेऽग्निभिरेतानीते च तत्फलात् (?)
चैकैकाद्ययुज्ञाहृतेषु परिधेर्भेदो युगो नैक्ययोः ।
एवं चात्र परार्ध-विस्तृति-महावृत्तस्य नाहोक्षरैः
स्याद् भद्राम्बुधि-सिद्धजन्म-गणितश्रद्धास्मज(?)भूपगीः ॥

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[11] Prof. H. P. Bhatta, Vedashala Observatory (Private communication).

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Here $\pi = 3.141592653589,234626433$

The above is the same series as the later known Gregorian Series (1670 A.D.)

$$\pi = 6\tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 6\left\{\frac{1}{\sqrt{3}} - \frac{(1/\sqrt{3})^3}{3} + \frac{(1/\sqrt{3})^5}{5} - + \ldots\ldots\right\}$$

As Śaṅkara Varma developed it earlier it should be called after his name. Recently Śrī Śaṅkarācārya of Puri using कटपयादि system has derived some formulae from *Ṛgveda* etc.[12] but these are to be critically studied.

The development of the theory of Numbers in India is very interesting and very remarkable. Āryabhaṭa gives Kuṭṭāka (method for indeteriminate equations of first degree) and Brahmagupta gives method for indeterminate equations of 2nd degree (Varga-Prakṛti) and Chakravāla was given by Bhāskarācarya. Before the time of Lagrange these are the best inventions in the theory of Numbers. As Jacobi has remarked the preservity of fate has wiled these methods. In Varga-Prakṛti "Valli-Paddhati" is a great advancement and it specifies the link with the theory of continued fractions due to Sanderson of England or due to Lagrange in France.[13] The method of congruences was never current in Indian literature. But all problems were easily solved. Here it will be interesting to point out that in the solution of

$$Y^2 + I \equiv O(MO\d{D}N)$$

Bhāskarācārya says—

रूपशुद्धौ खिलोद्दिष्टं वर्गयोगो गुणो न चेत् ।

i.e. the problem is wrong if N cannot be expressed as a sum of two squares. This was later proved by Deron Pale through rigorous treatments. The Bhakshali Manuscript also deals with mathematics. The author has advanced the Valli-methods quite a lot and claims this method to be more efficient than the ones commonly used these days.[13] The equation $Nx^2 + A = y^2$ should be called Brahmagupta equation and the same equation with $A = 1$ (the so-called Pellian equation) should be referred to as Bhāskara equation.

Āryabhaṭa in 5th century A.D. introduced progressions, Algebraic identities, and indeterminate equations of 1st degree. It is well known that Āryabhaṭa was famous among Arabs under the same "Arjbhar" and that about the 9th century A.D. Arabs learnt Astronomy from the Hindus. Sindhind was equivalent to Siddhānta. Alberuni says that the earlier astronomers referred to the works of Āryabhaṭa and other Siddhāntas. For example, he says that they imagined that Arjaphar meant a thousandth part and that afterwards they mutilated the word, and wrote "Azrabhar". Further Alberuni writes: "The book Sind-Hind is called by them (Hindu) Siddhānta", and again, "a Kalpa is that span of time which Muslim authors call the year of Sind-Hind".

The Yuga system developed in India quite independently and not by contact with Greeks. The Cycle of 180000 (Heraclitis), 120000 (Orphaus), 360000 (Cassandrus) years and Chaldean Cycle of 432000 years were not known to Indians.

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12. Śaṅkarācārya, *Vedic Mathematics*.
13. Dr. S. D. Sharma, 'Indian Theory of Numbers', *Historia Mathematica*.

Partial fractions were unusually used in Astronomical computations. Asakṛt-karma (the approximation-method) was used quite frequently. Law of Gravitation in qualitative form was kown to Indians in the Gupta Period.[14] Aristotelian School is believed to have some notion about the Law but that school did not have so refined and generalised notion, as the Indian School was having in the Gupta times and developed later upto Bhaskara's and Raṅganāthə's schools. Even in the work by Kaṇāda (6th century B.C.) there is found the definition of *Gurutva* quite consistent with the modern notion of the law (notion not defective like that of Aristotle). Some authors are not able to interpret the definition of "*Gurutva*" by Kaṇāda[15] quite to the point. The law was generalised by Bhāskara School for earth and later the attraction between particle and particle was postulated (Raṅganātha School) but no derived units were defined. Here we mean to say that the Vector quantities did not start before Newton.

The wave-theory of sound in qualitative form was discussed in Nyāya philosophy.

वीची-तरङ्ग-न्यायेन तदुत्पत्तिः प्रकीर्तिता ।

But the quantitative treatment was not given by any mathematician before Hyghen in the 17th century A.D..

In Nyāya and Vaiśeṣika Schools the पीलु-पिठरपाकवाद contains the germs or some postulates of Kinetic theory of gases, but still qualitatively. All approaches are based on Boolean-like algebra in these treatises.[16]

It is worthwhile to point out the notion of Indian philosophers about the smallest unit of time. It is the time taken by an atom in traversing its own extension. The atomic theory and its basic postulates were given by Kaṇāda before Dalton in the Occidental schools.

The concept of "Guṇa" in Sāṅkhya and Yoga philosophy is being treated by many scholars, including the present author and another one at Philadelphia at the Pennsylvania University, on the basis of quantum mechanics and field theory. The "Tattvas" of Sāṅkhya are being generated as eigen-states of Prakriti. We may emphasise here that it is pointed out by a Japanese quantum physiscist Dr. Sakuraithat the null creation and annihilation operators are represented by Brahmā, Viṣṇu and Maheśa. The triad in Indian thought, as philosophers know, represents the dominance of one guṇa over the other. The author is much hopeful that applying the notion of proper degeneracy of states, the "tattvas" can be generated. The metaphysical contributions of Kapila are definitely very important.

We do not believe that every credit should be given to these authors but whatever is original should be attributed to the respective scholars and the remarks about other developments are necessary from historical point of view. The authors must be given all due credit even if their works were not well exposed.[17]

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[14] *Sūryasiddhānta* with *Vijñāna Bhāṣya*.

[15] S. D. Sharma, 'Constituency of the definition of Gurutva and Dravatva in Nyāya with the modern law of gravitation', being pub. in *Viśva Saṃkṛtam*.

[16] Boolean Algebra used in Computer techniques.

[17] I am thankful to U.G.C. of India for financial support to my work.

CHEMICAL AND IATROCHEMICAL CLASSIFICATION AND PROCESSES AS PORTRAYED IN RASAŚĀSTRA TEXTS

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Introduction

Rasaśāstra is an important branch of learning in the field of Indian Medicine (Āyurveda). Initially Rasavāda was closely associated with Alchemy or Alchemical practices, which is nearer to chemistry than medicine. But after sometime when the concept of Dehavedha (metabolic transformation) was developed, through the science of mercury, its processings and by-products, to such an extent, so as to be capable of removing or preventing all types of diseases and decay, that the medicinal aspect of Rasavāda became more popular and this branch of learning and treatment named as '*Rasaśāstra*', '*Rasacikitsā*' came into existence.

From the historical point of view it is very difficult to trace its origin. Still on the basis of Albiruni and other references it could be said that this branch of learning flourished in India after the period of Vāgbhaṭa II *i.e.*, from 8th or 9th cent. A.D. and was developed to a fairly high degree between 9th to 13th cent. A.D., though it was practised even in earlier times.

The term 'Rasa' denotes Mercury which was considered the most important material possessing the power of amalgamating[2] all the metals and minerals in it. Rasa Śāstra means the science related to this metal and its Saṃskāras (special processings), which are 18 or 19[3-4] in number and are capable of making the mercury so potent that it could perform both Lohavedha (metallic transformations) and Dehavedha (metabolic transformations). The term 'Lohavedha' was concerned with Rasavāda (Alchemical practices) while the term 'Dehavedha' was concerned mainly with prevention and treatment of diseases.

The final aim of its development was to achieve Bhukti[5] (Physical pleasure) and Mukti (emancipation) through these processes. Initially Siddhas and Tāntrikas were engaged in the experiments for achieving Lohavedha with the view to remove poverty[6] and misery from the world. On the basis of their experimental observations they selected Mercury for this purpose and developed 18 Samskāras to remove its impurities as well as to potentiate it in such a way that it may acquire the power of transforming or transmuting lower or base metal into higher or precious metal, as

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1. *Albiruni's India*, Dr. Edward C. Sachau, S. Chand & Co., New Delhi. 1964. Vol. I, page 189.
2. *Rasaratnasamuccaya*, (*R.R.S.*), Rasavāgbhaṭa, Sri Venkatesvara Press, Bombay. 1 :77.
3-4. *Pārada Samhitā* (*P.S.*), Niranjan Prasad Gupta, Sri Venkatesvara Press, Bombay, page 74.
5. *Rasārṇava Tantra*, Bhairava. Chaukhamba Sanskrit Series, Banaras City, 1939 ; 1 :46.
6. *R.R.S.*, Sri Venkatesvara Press, Bombay, 1 : 31, 36.

they knew that if this could be made possible the poverty and misery of the people could be removed. They succeeded in their efforts to a great extent and some of them seem to have claimed that they were able to produce gold or silver in adequate quantities.

They were also able to get the mercury potentiated in such a way that when administered internally it could produce the effects of 'Dehavedha[7] without exhibiting any harmful or toxic effects on the human body. It should be mentioned here that they developed a special method of 'Kṣetrīkaraṇa'[8] (preparation of the body) also for this purpose and considered it as an essential[9] pre-requisite (pūrvakarma) before using the mercury internally.

The Indian Rasācāryas also showed their keen interest in the by-products of these processes and started to use them for therepeutic purposes with a view to prevent disease or decay, to prolong life, and to cure diseases, They succeeded in this task also and as a result an important branch of théreapy named 'Rasacikitsā' was developed in India, as elsewhere, as an important outcome of alchemical practices. It is worthwhile to note that the emergence of Rasacikitsā marked a turning point in the history of medicine in India, as its impact on the practice of Indian Medicine, which had suffered a setback during this period, had helped much in re-attainment of its previous position or even more than that and became the then treatment of choice.

In addition to mercury, many other metallic, mineral, stone, vegetable and other organic substances are used for this purpose but they stand after mercury in order of preference.

Chemical and Iatrochemical Classification:

The literary study of Rasaśāstra texts reveals that in addition to Rasa (Mercury) ancient Rasācāryas used various minerals and metals along with some stone, vegetable and organic substances to potentiate mercury for the purpose of Lohavedha and Dehavedha and classified them in the following groups on the bais of their chemical and Iatrochemical re-actions observed in relation to mercury and its processing *viz.*, Mahārasa,[10] Uparasa[11], Sādhāraṇa rasa[12] etc.

The substances included in 'Mahārasa' group are claimed to be the most superior drugs from the point of view of their usefulness in mercury-processings. Usually they are eight in number, but according to some texts there are some additions or alterations in one or two cases. The drugs of Mahārasas are Abhraka (Mica), Vaikrānta (Manganese ore), Makṣika (Pyrites), Vimala (Iron pyrite), Adrija or Śilājatu (Bitumen black or mineral pitch), Sasyaka (blue vitriol), Capala (Bismuth ore) and Rasaka (Zinc ore).

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7. *Rasārṇava Tantra*, Bhairava, C.S.S. Banaras. 1 : 21.

8–9. *Rasendra-cintāmaṇi*, Rāmacandra ; Jeevan and Vidya Sagar Bhattacharya, Calcutta ; 1916 ; page 24.

10. *R.R.S.*, Sri Venkatesvara Press, Bombay, 2 : 1.

11. *R.R.S.*, Sri Venkateswara Press, Bombay, 3 : 1.

12. *Rasendracūḍāmaṇi*, Somadeva. Motilal Banarasidas, Varanasi ; 1932 : 11 : 84-85.

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The substances included in 'Uparasa' group stand second in the list or the second best on the basis of their usefulness in mercury-processings. They are also eight in number and may differ in one or two cases according to some texts. The drugs of 'Uparasa' group are Gandhaka (Sulphur), Gairika (Ochre or Iron ore), Kasīsa (Iron sulphate), Kaṅksī or Sphaṭika (alum), Talaka (orpiment), Manaḥśilā (Realgar), Añjana (Gelena) and Kaṅkuṣṭha (Rhubarb).

The substances included in 'Sādhāraṇa rasa' group stand third on the basis of their usefulness for the purpose mentioned above. They are also eight in number and may differ in some cases as above. The drugs of 'Sādhāraṇa rasas' are Kampillaka (Mallotus philippinensis), Gaurīpāṣāṇa (Arsenic), Nava-sadara (Ammonia compound), Kapardika (Marine shell), Vahnijara (a substance of animal origin obtained from sea), Girisindūra (Red-Oxide of mercury), Hingula (Cinnabar) and Mriddarśṛṅga (Litharge or Lead Oxide).

The substances included in the above groups are not only of mineral nature but some vegetable and organic drugs are also included, which proved useful to mercury and its processes.

Lohas and Upalohas:

According to Rasaśāstra texts nine substancse are included in the above groups. The term 'Loha' means the metal extracted from the ore *i.e.*, **धातुर्लोहे 'लुह' इति मतः सोऽपि कर्षार्थवाचि । रसचूडामणि १४/१.**

'Upaloha' means inferior or alloys of the metals.

Ancient Rasācāryas described only six[13] metals initially *viz.*, Suvarṇa (gold), Rajata (Silver), Tāmra (Copper), Ayas (Iron), Nāga (Lead) and Vaṅga (Tin). The Yaśada (Zinc) was added to this group from 14th cent. A.D. by Madanapāla. In the 'Upaloha' group Ghana (brass), Ghoṣa (bell-metal) and Vartaloha (Alloy of copper, iron, brass, bell-metal and tin) were included. Some authors used the term 'Dhātu'[14] for 'Loha' and 'Upadhātu'[15] or 'miśra-loha'[16] for 'upaloha'.

Ratnas and Upa-ratnas:

Indian Rasācāryas knew the importance of Gems also in relation to mercury and its processings specially for its Bandhana[17] (solidification or fixation) and Māraṇa (incineration). According to texts Gems used for this purpose are classified as Ratnas and Uparatnas on the basis of their utility, potency and physical properties. Nine drugs have been mentioned as 'Ratnas'[18] such as Hīraka (Diamond), Māṇikya (Ruby), Nila (Sapphire), Tārkṣya (Emerald), Puṣparāga (Topaz),

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[13] *Rasārṇavatantra*, Bhairava. Ch. S. S. Banaras; 1939; 7 : 97.

[14] *Rasapaddhati*, Vindu. Nirnaya Sagar Press, Bombay, 1925, 1 : 19.

[15] *Sārṅgadhara Samhitā*, Śārṅgadhara, Nirnaya Sagar Press, Bombay, 1920; M. K. 11 : 1, 35.

[16-17] *R.R.S.*, Sri Venkatesvara Press, Bombay; 5 : 1, 4 : 1.

[18] *R. Cūḍāmaṇi*, Somadeva; M.L.B., Varanasi; 1932; 12 : 1.

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Vaiḍūrya (Cat's-eye), Gomeda (Hessonite), Muktā (Pearl) and Pravāla (Coral). Out of these the first five are called as Vara[19] (superior) Ratnas and the remaining four as 'Ratnas' on the basis of their physical structure, character and cost. Six drugs are included in Uparatna[20] group and these are inferior to Ratnas. They are Vaikrānta (Turmuline or flour spar?), Sūryakānta (Sun-stone), Candrakānta (Moon-stone), Rājāvarta (Lapis Lazuli), Perojaka (Turquoise) and Sphaṭika (Pebal or Rock-crystal).

The substances included in Ratna and Uparatna groups are of stony nature except Muktā and Pravāla which are of organic nature and are obtained from sea.

In addition to the above minerals, metals and stones Rasācāryas seem to have mentioned some other drugs also for this purpose *viz.*, Lavaṇas (Salts), Kṣāra (Alkalis), Viṣas. (Poisons), Upaviṣas (Mild poisons) and some drugs of vegetable origin. The Lavaṇas and Kṣāras are used mainly in the preparation of 'Vidas'[21] of different kinds which help in improving digestion and assimilation (Caraṇa and Jaraṇa) power of mercury especially during 'Jaraṇa' process. In the same way Viṣas and Upaviṣas are used for doing its Pakṣacchedana[22] (to make it thermostable) and for stimulating its appetite.

According to Rasa literature 5-9 Viṣas and 5-7 Upaviṣas are mentioned which improve the amalgamating power of mercury and make it thermostable to a great extent.

The Drugs of vegetable origin are also grouped in the following groups on the basis of their activities *viz.*,

1. Mārakauṣadhis[23]
2. Bandhakarauṣadhis[24]
3. Drāvikauṣadhis[25]
4. Kramikauṣadhis[26]
5. Divyauṣadhis[27] and
6. Niyāmakauṣadhis.[28]

Important Processes related to Mercury and others

1. *Samskāras:*

Indian Rasavādins (Alchemists) developed eight and/or eighteen Samskāras (special processings) of mercury for potentiating and changing its physical, chemical and physico-chemical characters to such an extent that it may lose its quick moving property and may become fire-proof or thermostable and when this is attained it may acquire the power of transforming or transmuting a base metal into a precious one and may turn into Gold or Silver by itself.

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[19] *R.R.S.*, Sri Venkatesvara Press, Bombay ; 4 :4.

[20] *Rasataraṅgiṇi*, Sadānandā Śarma ; 23 : 154.

[21] *R.R.S.*, Sri Venkatesvara Press, Bombay ; 8 :76.

[22] *P.S.*, N. P. Gupta ; Sri Venkatesvara Press, Bombay ; page 134.

[23, 24, 25, 26, 27 & 28] *Rasārṇava Tantra*, Bhairava ; Ch.S.S., Banaras, 1939, 5 : 1-25.

The eight Samskāras[29] are:—

1.	Svedana	Perspiration or steaming.
2.	Mardana	Rubbing.
3.	Mūrchana	Swooning.
4.	Utthāpana	Restoration of its lost form.
5.	Patana	Distillation.
6.	Bodhana	Stimulation.
7.	Niyamana	Restraining.
8.	Dīpana	Appetisation.

These are considered useful for removing impurities and potentiating mercury for ten further Samskāras. These are common for Dhātuvāda and Rasāyanavāda.

Further ten Samskāras[30]:

9.	Grasamāna	Division of Grass or Fixing of Grass weight
10.	Caraṇa	Mixing of Grass.
11.	Garbhadruti	Intrinsic liquification.
12.	Bāhyadruti	Extrinsic liquification.
13.	Jaraṇa	Digestion and assimilation of Grass (metals) in the mercury.
14.	Rañjana	Colouring
15.	Saraṇa	Preparation for Kramaṇa.
16.	Kramaṇa	Penetration or Transmission.
17.	Vedhana	Transformation or Transmutation.
18.	Bhakṣaṇa	Internal administration.

These are usually considered useful for Dhātuvāda as their main aim is to make the mercury fit to transform a base metal into higher or precious metal for the purpose of Lohavedha and for Dehavedha also.

Process or Vedhana (Transformation):

The main aim of the above Samskāras is to produce a power of Vedhana (Transformation) in mercury. Its details are discussed as follows:—

Vedhana is one of the eighteen Samskāras and is an important and final outcome of different mercurial processings. According to texts different types of Vedhas are described. The *Rasaratnasamuccaya*[31] describes its five types as follows :

1. Lepa— here Vedha is produced by application.
2. Kṣepa ,, ,, ,, by emersion.

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[29] *Rasendra-sārasaṅgraha*, Gopālakrishna, Chaukhambha Sanskrit Series, Banaras, 1938; 1 : 49-50.

[30] *P.S.*, N.P. Gupta ; Sri Venkatesvara Press, Bombay, page 75.

[31] *R.R.S.*, Sri Venkatesvara Press, Bombay ; 8 : 79-84.

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3.	Kunta	,,	,,	,,	by emersion.
4.	Dhūma	,,	,,	,,	by application of fumes.
5.	Śabda	,,	,,	,,	by air blown through mouth.

The *Rasaratnākara* also describes five types of Vedhas as follows: 1. Dhūma 2. Sparśa, 3. Śabda, 4. Peṣaṇa and 5. Medinī-Vedha. Its author has taken the first three types from above and added Peṣaṇa and Medinīvedha as new types, which shows its further advancement in this direction. According to him a whole mountain could be transformed into gold and likewise a particular area of the earth may also be transformed into gold, and several methods have been described for the same.

Apart from this the *Rasaratnākara* describes the method for making the mercury potentiated in such a way that when taken internally it endows the man with the power of levitation *i.e.*, moving in air as per his wish and the same is called the method of **त्रैलोक्यव्यापित्व**. In addition to this it described also the methods for making artificial gems such as Māṇikya-karaṇa, Gomedha-karaṇa, Vajra-karaṇa etc.

Process of Bandhana (solidification):

The natural liquid-form of mercury may have created an interest in ancient Rasācāryas to develop a process that is capable of converting the mercury into a solid or alloy form, and the process developed for the same in Bandhana, which by changing some of the physical properties of mercury may be able to convert it into a solid state. Thus Bandhana is nothing but a process of making alloys through Mercury. The aims of Bandhana are to check its **चाञ्चल्य** and **दुर्ग्रहत्व** as stated in *Rasaratnasamuccaya*.

According to the texts the following types of Bandhanas are described depending upon the nature of the substances used for the purpose:—

1.	Mūlikā-bandha—through			herbs, best.
2.	Maṇi-	,,	,,	gems, better
3.	Dhātu-	,,	,,	higher metals, good.
4.	Pūti-	,,	,,	lower metals (lead or tin), inferior
5.	Druti-	,,	,,	liquified Mica etc. good

The *Rasaratnasamuccaya* describes twenty-five types of Bandhana and mentions that some ācāryas described Jalūka Bandha as the twenty-sixth type and could not be used internally. *Rasaratnākara* mentions twenty-one types of Bandhas.

It is clear from the above descriptions that substances like herbs, gems, higher metals, lower metals and liquidified mica etc. are used for solidifying mercury. These are either metals or contain some inorganic substances in smaller or larger quantities and when mixed with mercury may form an amalgam or alloy which, may convert it into solid states depending upon the quantity and nature of the inorganic material added.

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Process of Sattvapatana (metallic extraction) :—

As the Sattvas (extracted metals) are the main substances recommended for the process of Jaraṇa (Digestion and Assimilation), Indian Alchemists had to develop the method for the same,

Sattvapatana (metallic extraction) is an important process of Indian Rasavāda, especially from the point of view of mercury-processing. Initially it was considered the most difficult one but gradually it became a common process and almost all the minerals were extracted through this process by the Rasācāryas and the Sattvas thus obtained were used for both mercurial and therapeutic purposes. They developed special type of furnaces for this purpose as they knew that some of the minerals require high degree of heating for their extraction. Not only this, they also mentioned the colours of different Sattvas which shows their deep knowledge and interest in this process. Abhraka (Mica), Makṣika (Pyrites), Kānta-pāṣāṇa (Loadstone), Rasaka (Zinc ore), Sasyaka (Blue Vitriol) etc,, are the few examples of minerals usually employed for this process,

Process of Druti (Liquifaction) ;

Indian Rasavādins were also very fond of making Drutis (Liquifaction) of different metals and minerals as in their opinion these when mixed with mercury could be easily digested and assimilated and complete Jaraṇa could be done within a short period. Drutis are nothing but a liquified form of a metal in some solvent. Two types are described in the text, *viz.*,

1, Garbha - druti - that which is done inside the mercury.

2, Pāhya - druti - that which is done outside and then used for mercury processings or other purposes, This is evolved with the aim to keep the metals and minerals in liquid state for ever. And they have described various methods for this purpose, Usually Abhraka (Mica), Abhraka Sattva (essence of Mica), essence of Pyrites, Gold, Silver, Iron and other metals and Vajra, Vaikrānta and other gems are used for this purpose,

Process of Māraṇa (Incineration):

This is a process which reduces metals and minerals to ash-form through grinding and heating called Pūta.[32] The term Pūta represents grinding and measured heating or roasting of a substance, The object is, however, to convert the material to a suitable dosage form, by disintegrating the substance to a fine state of subdivisions, so that it may be absorbed into the system easily. According to texts Māraṇa of any substance is considered best when it is done by adding mercury and its compounds only. When it is done with the vegetable extractions it is considered as medium *i.e.*, neither good nor bad, but when sulphur or its compounds are used it is considered as bad or inferior and when Arilohas (other metals) are used for Māraṇa it is said to be rather harmful.

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[32] *R.R.S.*, Sri Venkatesvara Press, Bombay ; 10 ; 50,

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Thus we may assume that adding of mercury in the process of Māraṇa makes the product (Bhasma) very much useful. The other ingredients mentioned above do not make the preparation so much useful.

Process of Śodhana (Purification):

This is also one of the most essential and important processes, which initially removes the impurities, reduces toxic and untoward effects and in some cases helps to increase the therapeutic and other properties of the materials for which it is employed. The process is divided into two divisions, Sāmānya (ordinary or common) and Viśeṣa (special or specific) Śodhana. According to texts different types of operations such as Svedana, Mardana, Nirvāpa, Niṣeka, Patana, Bhāvana, Bharjana etc., and drugs have been described for the same. Śodhana process is recommended particularly for mercury, metals, minerals, gems and poisons and generally for all types of drugs.

This shows how much progress was made by the Indian Rasavādins (Alchemists) during the period 9th to 14th century A.D.

Thus it can be seen that the ancient Rasācāryas selected mercury as the most powerful chemical substance with the object of achieving Lohavedha (metallic transformation) and Dehavedha (metabolic transformation) with the ultimate aims of enjoying Bhukti (physical pleasure) and Mukti (emancipation) in this world. To achieve the above aims and objects they developed different types of Saṃskāras and processes for potentiating mercury in such a way that it may acquire the power of transforming an imperfect metal to the perfect one and may act as a powerful transmuting agent for both man and metal. Many drugs of diverse nature are used in these processes and have been classified on the basis of their usefulness and potency shown in relation to mercury and its processings.

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FERTILIZERS IN ANCIENT INDIA

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Ancient Indian seers had established that plants were also living beings with the difference that their consciousness (Saṁjñā) was internal or dormant. All the same, they have feelings of both pain and pleasure. Sir J.C. Bose had demonstrated this fact to learned assemblies in many parts of the world. Just as preventive and curative medicines are prescribed for human beings, even so are they done for members of the vegetable kingdom. In ancient works on Śilpaśāstra (architecture) and in Kauṭalya's *Arthaśāstra* as well as the *Bṛhat Saṁhitā* of Varāhamihira we come across sections dealing with trees or Vṛkṣāyurveda (treatment of plants) in connection with agriculture, gardening and town-planning. In the *Atharva Veda* too there are prayers for the sweet and juicy fruits of trees and creepers.

In Sanskrit poems and dramas we come across the word *Dohada*, which, applied to plants, means special treatment or manure or fertilizer. In the *Ratnāvali* there is the famous verse, "Uddāmotkalikām...." which speaks of the wonderful appearance of abundant flowers on the King's jasmine creeper as a result of the application of a *Dohada*, fertiliser, supplied by a hermit. There is also the case of the Dohada coming under what are called *Kavisamayas*[1] or poetic conventions. Rājaśekhara argues that the poetic conventions, fictitious as they may appear, are not to be rejected by poets. For, ancient scholars, well versed in the Vedas and their ancillaries as well as the Śāstras, had roamed over many islands and countries, and written these things on the basis of their first-hand knowledge. These things appear strange and untrue as a result of vast changes in climatic conditions, times and other circumstances. This is how the poetic conventions originated in days of yore.

These poetic conventions relate to other classes also such as birds and beasts. The Cakora birds drink nectar from the Moon's rays; the Cakravākas get separated from their mates at night; the Cātaka can drink water that drops from the clouds. The deer are enraptured by the tunes of hunters and thereby get ensnared. The swan is supposed to possess the capacity to separate milk and water. The bee dies by kissing the Campaka flower etc. etc. We are not concerned at present with these poetic conventions, but only with the special treatment given to plants for increasing their yields. This subject of fruit and flower culture as well as grafting was practised in ancient India under the aegis of the rulers. This knowledge was also hereditary in some families.

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[1] "Aśāstrīyam alaukikam ca paramparāyātam yam artham upanibadhnanti kavayaḥ sakavisamayaḥ" and "Kavimārgānugrāhī kathaṃ eṣa doṣaḥ" iti yāyāvarīyaḥ"—Ch. XIV of Rājaśekhara's *Kāvyamīmāmsā*.

According to poetic conventions the Aśoka tree should bear abundant flowers if it is kicked by a charming young lady producing the jingling sound of her anklets. On the face of it, it would look ridiculous and superstitious, especially to a person of scientific outlook. However, we have to remember that many a scientific discovery owes its inspiration to some so-called superstitions. Though the ancients, who were fond of myths and parables, couched their thoughts not in scientific terms but in figurative language, yet their statements have the value of practical utility and traditional authority. If we analyse these *conventions* with a scientific spirit, I am sure, we may stumble on the truth lying underneath. I think that the jingling anklet subjects the Aśoka tree to sound or music therapy in addition to giving it mild physical vibrations. It is well known that plants need water, light etc. to prepare their food. Similarly they depend upon another physical agency *viz*., sound, which has some influence on their physiology. Music is said to cast a spell on all living beings, as it is 'the food of love'. Experiments were conducted recently by subjecting certain plants and creepers to different tunes in order to find out their effect on their produce. Scientists have come to the conclusion that music does influence by and large the life and growth of plants and their yields. In this connection let us turn to what Dr. T.C.N. Singh, Retd. Prof. of Botany, Annamalai University, has to say: "If they depend on light, why not on sound?" He discovered under microscopes that protoplasm was moving faster in the cell as a result of the sound produced by an electric tuning fork. This discovery led to his conclusion that sound must have some effect on the metabolic activities of the cell. His findings are that the sound of the vīṇā produces better results than that of violin. He says further that male voice is healthier to the plant than female voice[1]. Among the Rāgas or tunes, he says, the Garukesi is the most helpful in increasing the yield. Originally, it is said, such experiments were conducted in the U.S.A., Canada, Russia etc. In the West Bacch Sonnetta (A & B) was found to be very potent. Dr. Singh is of opinion that the growth and development of forests is largely due to the presence of a large number of birds singing several tunes every day.

As mentioned above, the subject of *Dohada* is often met with in Sanskrit literature. Śrīharṣa (12th century A.D.) who was well versed in many branches of learning, refers in his *Naiṣadhīyacarita* to the fertilizer used for the pomegranate. While explaining the word *Dohada-dhūpinī* the commentator Nārāyaṇa[2] says that Dohada is that material by which an extraordinary growth of fruits etc. is achieved; in the particular context the Dohada or Fertilizer was fumigation. The editor Pandit Śivadatta has quoted from some source three verses which mean "Dohada is that material evolved by competent persons for producing flowers etc. on trees, bushes, creepers and the like, out of season". The next two verses mention the materials used for fumigation : "For increasing the yield of pomegranates the best procedure is to pour on the tree the liquid of mutton and to fumigate it by burning sheep's wool and mutton underneath. If the same tree is smeared with a paste made of fish-meal, ghee and Triphala as well as with the flesh of goats and sheep, and fumigated with the latter, its fruits will be as big as those of the Tāla tree."

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[1] Manipal Record Vol. IV-36, page 2.

[2] *Naiṣadha* I-82.

The subject of treatment of trees has been ably dealt with by Varāhamihira in the *Bṛhat Saṁhitā*, chapter LV, as it forms part of the topic of Gardening. Corresponding to the Green Manure employed in modern times Varāhamihira speaks of the Sesamum treatment for the soil. According to him if flowers or fruits are destroyed suddenly, the concerned tree or creeper should be watered with milk cooled after being boiled with horse-gram, black gram, green gram, seasamum and barley. Another recipe is the following : Trees, creepers and bushes should be sprinkled daily with a mixture of two Āḍhakas *i.e.*, 128 Palas of the powder or the dung of goats and sheep, one Āḍhaka of sesamum, one Prastha *i.e.*, 16 Palas, of wheat-particles, one Tulā (100 palas) of beef and one Droṇa (256 Palas) of water kept for seven days.

The *Abhilaṣitārthacintāmaṇi* mentions a few fertilisers: (i) The soil underneath a tree struck by lightning is good for warding off trouble for trees from snowfall. (ii) Fumigation of trees by burning turmeric, Viḍaṅga (Erycibe Paniculata), white mustard, flowers of the Arjuna tree, mixed with fish and the flesh of Rohita (a kind of deer) will not only help the growth of flowers and fruits but will destroy all worms and insects as well as diseases. (iii) Fumigation of a tree by burning Viḍaṅga, asafoetida, Sindūra, pepper, Ativiṣa, Vacā, Bhallātaka and buffalo-horn mixed in equal quantities will destroy all kinds of insects and germs. (iv) Fumigation caused by burning fish, clarified butter, white mustard and banana leaves will cause a bumper crop (v) To produce fruits out of season, the tree should be watered with a decoction of Aṅkola mixed with ghee and honey and with the fat of parrots and the deer. (vi) Milky trees will yield a bumper harvest if they are watered with milk mixed with Viḍaṅga, honey and ghee, and fumigated with the smoke of burnt Naṭa and Kuṣṭha, (vii) The same effect will ensue in case the trees are scratched with thorns and fumigated with cow's ghee, water, and the fat of parrots and rats. (viii) Vines will bear sweet fruits in abundance when they are manured with the excreta of cocks and the liquid of horse's flesh. (ix) Orange trees manured with any flesh mixed with cow's milk and jaggery will bear plenty of fruits. Similar recipes are given in this work for mango, banana, wood apple (Kapittha), myrobalan, cocoanut, jujube, tamarind and such other trees.

Recently there appeared in the South Kanara district of Mysore State a peculiar disease of the roots of the banana plant which has practically destroyed entire plantations. The *Abhilaṣitārthacintāmaṇi* mentions a remedy for such a disease : The roots of the banana are to be scratched with a gold needle heated in the fire caused by burning the powder of some article (which is not clear). The Bījapūra plant will yield big fruits if it is manured with oilcake, liquor and fish and then watered.

The jasmine, which is considered the queen of flowers in India, will bear flowers when it is burnt with the fire of chaff.

There are some plants that bear flowers having no smell at all. There are fertilizers for making such plants bear sweet-smelling flowers. Such plants are to be manured with the soil taken from the buds of plants bearing fragrant flowers, and watered with a mixture of water, and the powder of Gandhapatra, Mustā (Cyperus rotundus), Tagara (Tabernaemontana coronaria) and Uśīra (Andropogon muricatus).

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It is well known that the Āmalaka fruit is astringent, but there are recipes for making it sweet. The tree should be scratched before the appearance of flower with a twig of the Kumaraka (Tamāla according to the *Dhanvantari Nighaṇṭu*), and the scratched surface besmeared with a paste made of Japā, sesamum and equal quantities of honey and ghee, the mixture appearing like mire. Similarly the tamarind fruit can be turned sweet, if the tree is watered with a decoction made of the leaves of Jambu, Uśīra and Mustā, or with one made of milk and flesh and serum of the deer, parrot, antelope and jackal. Creepers besmeared with honey will produce red flowers, whereas with ghee they will bear white flowers. The lotus and lily too will have two flowers on a single stalk, if the plant is smeared with honey and ghee and manured with the powder of Kalāya and mire.

Injections to roots are also prescribed here for specific purposes : A small ball of the flower of Yaṣṭimadhūka, the white Kuṣṭha and honey should be injected into the root of any tree, if it does not bear fruits.

There is a recipe for making the fruit ever-green ; The branch of the tree should be wound round with cloth in seven rounds and at the joint of the trunk and branch it should be well covered with the skins of deer and elephant.

A tree or plant is said to be capable of being transformed into a vine by means of the following fertilizer : The root of the mango tree (it may be in the early stage of its growth) should be manured with a decoction of Aṅkola, dog's flesh and goat's milk mixed with oilcake. Such a vine will bear fruit in all seasons.

Cross-breeding of plants which is now practised on a large scale was anticipated by the ancients when the seed of the Vārtākī (egg plant) mixed with honey and ghee is kept inside a Kūṣmāṇḍa (ash-gourd) for a week and then sown, the plant will come to have the leaves of the ash-gourd, but fruits of Vārtākī itself. Similarly the plantain-trunk is supposed to bear a pomegranate when it is watered with the flesh and serum of a boar and decoction of Aṅkola.

Just as pre-natal care or treatment is necessary for human beings, even so seed-treatment is profitable before sowing. All seeds are to be soaked in milk for ten days taking them out everyday with the hand smeared with ghee. Then they must be rolled many times in cowdung, fumigated with the flesh of deer and hog, and then with flesh and hog's marrow they should be planted. They should be sown in a prepared soil (with the sesamum treatment). Lastly they should be sprinkled with milk and water. Varāhamihira has prescribed in addition some special recipes for the treatment of the seeds of Tamarind, Kapittha and Śleṣmātaka. The tamarind seed should be sprinkled with a compound of the flour of rice, black gram and sesamum as well as particles of wheat and stale meat and repeatedly fumigated with turmeric powder. The *Abhilaṣitārthacintāmaṇi* gives some recipes for seed-treatment on similar lines; Ripe fruits without any blemish ought to be selected and dried in the sun. Then they should be coated with cowdung and fumigated with Viḍaṅga and ghee for five days. This is the general recipe for all kinds of seeds. Those of milky trees are treated thus : Soak the seeds for ten nights in cow's milk, dry them in the shade, and mix them with the ashes of Vyāghrī (or Bṛhatī), and of barley, and wheat. Lastly give them a coating of cowdung. Seeds kept in the oil of Nṛśaṃśa(?) and

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Aṅkola for seven days and then sown in a soil wetted with hailstones will sprout quickly. The pomegranate seed should be wetted 21 times with the blood of Kukura (or Kukkura?) before sowing for a good yield. Any seed soaked in milk mixed with the flesh and serum of fish and boar would be very effective. So would be a tamarind seed kept for seven days in milk mixed with the serum of fish and boar and with sesamum oil, and then smeared with the ashes of Bṛhatī and Tilakāṇḍa (sesamum plant). To make the fruit unusually big, wet the seed with water mixed with human flesh and serum as well as with the powder of ivory.

Before sowing the seed the soil should be tested. For fruit-cultivation the soil must contain sweet water and be free from pebbless. It must also be glossy and unexposed to frost. If sesamum, black gram and green gram grow luxuriantly, that soil is ideal for flower and fruit-cultivation. The pit of the trees should measure four feet deep and square. The pit too should be treated and manured : It should be filled with plenty of bones and cowdung and burnt. Then remove the ashes and fill the pit with a layer of sand at the bottom and another layer of the flesh and serum of goats over it along with water. After this the seed is to be sown in this pit. Instead of seed a tender plant may also be planted therein. Cooked white rice mixed with curds and rock salt is also thrown into the pits for good results.

This science of fertilizers or Vṛkṣāyurveda is very ancient, as Varāhamihira mentions many ancient authorities such as Sage Kaśyapa. The *Abhilaṣitārthacintāmaṇi* seems to be a compilation done by King Somadeva III of the Chalukyan dynasty. The date of the work is the first of Caitra of the Śaka year 1051.

The foregoing paragraphs, I am sure, will draw the attention of scholars and scientists, thereby helping them in further researches resulting in the extension of the horizon of human knowledge. My aim in this paper is to show that the ancients had evinced sufficient capacity and enthusiasm for analytical thinking and scientific experimenting even in those far off days when man's activities were guided more by belief than by reason.

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ZOOLOGY IN SANSKRIT LITERATURE

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It is a fact now well recognised that Sanskrit literature, especially of the ancient periods, is full of a wealth of knowledge which was based on actual observations of the people of those days and which is of great importance to the science today. While Mathematics, Physics, Chemistry, Technology, Astronomy, Architecture etc. have received their own share of knowledge from this literature, Biological Sciences like Zoology, Botany, Medicine and Agriculture have also not been the lesser gainers. On a close survey of Sanskrit literature from a Zoological point of view, the author has realised that this literature has a lot of information which can not only add useful chapters to the history of Zoology but can also bring out facts of importance to the various branches of pure and applied Zoology. Little has, however, been done to enearth this treasure. The present paper makes an attempt to reveal this knowledge both in *Vedic* as well as in *Classical Sanskrit* and also to give relevant references at the proper places to show what has been done in this field. The subject as presented here has been divided into convenient branches of Zoology, such as Natural History; Anatomy and Physiology; Reproduction, Embryology and Genetics; Origin and Evolution of Life; Taxonomy; Economic Zoology; etc. Contributions of Sanskrit to each of these branches have been described.

Natural History

Natural history deals with the life and behaviour of animals in their natural surroundings. From the earliest times the great Indian sages, writers and poets in Sanskrit had been living in close association with Nature, keenly observing her phenomena. They had their own emotions and inspirations from these phenomena and most of them had employed poetry as a medium of expression of those emotions. It is no wonder therefore that most of the scientific observations have been passed on by them through the medium of Sanskrit poetry. Kunhan Raja (1962, P. 217) correctly remarks that "from the earliest times, Sanskrit poetry has been noted for its Nature element. The *Ṛgveda* and the *Atharvaveda* are both high-class Nature poetry. So are the two *Itihāsas*, the *Mahābhārata* of Veda Vyāsa and the *Rāmāyaṇa* of Vālmiki, Kālidāsa and Bhavabhūti too come within the group of Nature poets. According to Macdonell (1899, p. 298), "Nature occupies a much more important place in Sanskrit plays. The characters are surrounded by Nature, with which they are in constant communion. The mango and other trees, creepers and lotuses, pale red trumpet flowers, gazelles, flamingoes, bright-hued parrots, and Indian cuckoos in the midst of which they move, are often addressed by them and form an essential part of their lives. Hence the influence of Nature on the minds of lovers is much dwelt on. Prominent everywhere in classical Sanskrit poetry these elements of Nature luxuriate

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most of all in the Indian drama." The Sanskrit treasure of Natural History is therefore rich and it only requires a thorough probe, proper understanding and correct interpretation to add to our modern knowledge about the habits and habitats of animals. A few examples should suffice to illustrate this fact.

The hymn VII. 103 of *Ṛgveda* is reproduced below in its English rendering from Macdonell (1899, p. 102):

Resting in silence for a year,
As *Brahmans* practising a vow,
The frogs have lifted up their voice,
Excited when *Parjanya* comes.

When one repeats the utterance of the other
Like those who learn the lesson of their teacher,
Then every limb of yours seems to be swelling,
As eloquent ye prate upon the waters.

As *Brahmans* at the mighty *soma* offering
Sit round the large and brimming vessel talking,
So throng ye round the pool to hallow
This day of all the year that brings the rain-time.

These *Brahmans* with their *soma* raise their voices,
Performing punctually their yearly worship;
And these *Adhvaryus* sweating with their kettles,
These priests come forth to view, and none are hidden.

The twelvemonth's god-sent order they have guarded,
And never do these men neglect the season.
When in the year the rainy time commences,
Those who were heated kettles gain deliverance.

From this hymn the following facts about the habits and habitat of frogs can easily be gathered;

(i) Before the beginning of the rainy season the frogs rest in silence, clearly pointing to their important habit of hibernation and aestivation.

(ii) With the first rain of the rainy season after summer they are stimulated to activity and utter their loud croaks.

(iii) In croaking one repeats the utterance of the other.

(iv) Their bodies swell up when they utter their loud croaks in their aquatic environment.

(v) On the first rainy day they throng and sit round a pool indicating their habitat in or near water.

(vi) There is a strict regular annual periodicity of the habits mentioned above.

It is needless to mention that even the most elementary text book of Zoology will confirm these habits and habitat of frog. Similes used in the hymn have given a graphic effect to the description.

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An etymological analysis of the Sanskrit words used for animals gives a good clue to some of their important habits and also to the habitat. The *Nāmaliṅgānuśāsana* or the *Amarakośa*, an important work on Sanskrit lexicography, gives seven synonyms for frog and each of them points to some of its important habits or habitat as follows :

1. *Bheka* - Terrifies.
2. *Maṇḍūka* - Gives a good look to the aquatic environment.
3. *Varṣābhū* - Occurs or appears during rains.
4. *Śālūra* - Possesses a fast gait, or shines.
5. *Plava* - Jumps or floats.
6 *Dardura* - Has a ear-tearing or loud croak.

Hora (1948*a*) has derived a lot of useful information about the Natural History of fishes from the 22 Sanskrit words used for them.

According to Rao (1957) there are references to over 250 species of animals, Vertebrates and Invertebrates, in Vedic literature and a wealth of information exists about their Natural History. The Vertebrates mentioned include all the five classes: Pisces, Amphibia, Reptilia, Aves and Mammalia ; while the Invertebrates are mostly Arthropods, the class Insecta predominating. Rao also mentions that in the *Agni* and the *Bhaviṣya Purāṇas*, there are a number of observations on the structure and habits of snakes, some of which according to him approximate to modern verified and recorded facts while others appear to be fanciful as yet.

Shastry (1963) gives the information that "the entire 24th chapter of the *Yajurveda* contains rich material regarding this branch (Zoology). More than a hundred animals and birds have been described. 21 kinds of snakes, male and female worms of various colours, microscopic bacteria and insects of terrestrial and aquatic origin have been referred to."

Hora (1951) points out that in *Suśruta Saṁhitā* there is a clear indication of the knowledge of fishes with special reference to their form in relation to their habits, habitats and locomotion. In another paper (1951) he refers to *Matsyavinoda* or a chapter on angling in the *Mānasollāsa* composed by King Someśvara in 1127 A.D. There are about 52 verses in this chapter containing references to about 37 different types of fishes. On the basis of characters and habits mentioned in the verses and also on the basis of the etymological analysis of the Sanskrit names used, Hora has made efforts to identify these fishes and has derived a good deal of information on their structure, habits and habitats.

Roy (1963) gives the Sanskrit names of about six insects, 7 fishes, 6 reptiles, 14 birds, and 34 mammals found in the *Rāmāyaṇa* of Vālmīki.

In the works of Kālidāsa there are vivid descriptions of the Natural History of a number of animals, such as corals, about 18 insects, 2 arachnids, 2 molluscs, fishes, frogs, snakes and crocodiles, 18 birds and 15 mammals. Gupta (1957, 1958, 1960*a b*, 1961, 1962) has examined in detail the ornithological information available from the works of Kālidāsa and has pointed out facts of importance available from them about the Natural History of pigeons, peafowls, cuckoo, sārasa crane, egret, and *hamsa* (a goose) respectively. He has referred to the acute observations of Kālidāsa on external features, habits, habitat, distribution, seasonal life, song, dance, courtship, breeding habits, parental care and migration, etc. of these birds. Further Gupta (1963) has also probed thoroughly the works of Kālidāsa from an entomological point of view and has gathered important scientific information from nearly 50 verses about the Natural History of 18 insects: *ali*, *bhramara*, *bhṛṅga*, *daṃśa*, *dvirepha*, *khadyota*, *lākṣā* insect, *madhukara*, *madhu-makṣikā*, *madhupa*, *patanga*, *pipīlikā*, *śalabha*, *saraghā*, *ṣaṭpada*, *śilīmukha*, silkworm, and *valmī*. He has made efforts to identify these insects and has revealed knowledge of Kālidāsa about insects concerning many facts of their habits habitat ; distribution ; external features ; gregarious nature; locomotion; senses of smell, taste and colour ; attraction to light and fire ; reaction to rain, wind and temperature ; mimicry; sound-production; luminosity, plant-associations ; seasonal life, courtship ; termitaria hills and termitophilous fauna ; as well as economic aspects such as pollination ; production of honey, of silk from cocoon, and of lac ; annoyance to man and cattle by bite ; locust-menace ; etc.

Anatomy and Physicology

Seal (1902) has shown that the Sanskrit writers like Caraka, Praśastapāda, Suśruta, Śaṅkara and Umāsvāti reveal in their works a familiarity with the anatomical details of animals and that Sanskrit literature contains advanced ideas on metabolism, circulatory system, nervous system etc.

Rule (1931) in his description of the Vedic gods as figures of biology, observes that " a blending of anatomical and physiological facts (masked in allegorical forms) with abstract physiological truths is there clearly evident in the teachings of the *Upaniṣads*. Shastry (1963) writing or Anatomy and Physiology of the *Vedas* remarks that " high-graded knowledge of various internal and external organs of the body and its various systems had been acquired by the Vedic Ṛṣis. Detailed references are available specially in *Atharva Veda* in this field also." According to Kutumbiah(1962), " From the point of view of the development of Indian medicine the rational element contained in the *Atharvaveda* is significant. In A.V.X.2 is a hymn in which the several parts of the skeleton are carefully and orderly enumerated. This enumeration formed the basis of the osteology of the *Ātreya Caraka* school of classic medicine. In A.V. 11. 33 almost all the important organs of the body are enumerated. In A.V. I. 17.5 are mentioned *dhamanīs* and *śirās*, names familiar in classic medicine."

Misra and Pandeya (1963) are of the opinion that the *Suśruta Samhitā* is the first ancient Sanskrit work which deals systematically and in great detail, with the development and anatomical structure of the eye, as well as with the physiological factors of the ocular apparatus in connection with the diseases of the eye.

Roy (1967) has dealt with in great detail the Anatomy in Vedic literature and in an abstract form, the observations made are as follows :

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"In the Vedic literature we meet with descriptions of the structure of the human body, which reveal that the anatomical knowledge of the Ancient Indians was of no mean order. In the present paper an account of this knowledge has been reported along with those developed in other contemporary nations of the world. Descriptions are found in the Vedic literature of all important bones and other bodily parts which confirm more or less to our modern knowledge.

This description shows an evolution of the anatomical knowledge of the Ancient Indians: The *Samhitās* represent a description of the general structure of the human body. In the *Brāhmaṇas* a detailed account of the chest, neck, back portion of the body, ribs, abdominal portion and the hand is found to occur. A similar account of the human heart, nervous system, sense organs is given in the *Āraṇyakas* and the *Upaṇisads*."

Caudhary (1967) refers to the fact that in the *Yājñavalkyo Smṛti* "Yājñavalkya mentions the six *dhātus* (primary substances), six constituent parts of the body, three hundred and sixty bones, and the five organs of action and perception. While mentioning the vital parts of the body, Yājñavalkya gives more or less a detailed description of the whole human body. The number of veins, sinews, arteries, muscles and nerves and also the number of the cavities throughout the whole body and also the quantity of the fluid in the body have been mentioned."

Murthy (1968) informs us that the *Brāhmaṇas*, a part of the Vedic literature in prose, show a clear understanding of Physiology based on Anatomy.

According to Mishra (1968) '*Agni Purāṇa*, an encyclopaedic work of about 10-11 century A.D., discusses, in course of its physiological deliberations, ideas on the development of human body, obstetrics, Physiology and Anatomy".

REPRODUCTION, EMBRYOLOGY, AND GENETICS

According to Macdonell (1899), there are two sacraments in the *Gṛhya Sūtras* aimed at the obtainment of the son. One is the *Pumsavana* sacrament (p.212) in which the pounded shoot of a banyan tree is placed in the wife's nostril. Another (p.214) is connected with one of the marriage ceremonies when the wife is conducted to her husband's house, seated on the hide of a red bull, and upon her lap is placed the son of a woman who had borne living male children. The ideas aim at methods of sex-determination and it requires proper interpretation and experimentation to appreciate how far, if at all, they are really scientific.

On the inheritance of mental traits, the two pedigress of the ancient Sanskrit works make interesting comparisons with the pedigrees studied in modern Genetics. Veda Vyāsa, the author of *Mahābhārata* was the "son of the *Vedic* poet *Parāśara* through a girl belonging to the fisherman community. The king of those days named *Santanu* met that girl at the same place and he fell in love with her and wanted to marry her. But he had already a queen and also a son, and the father of the girl refused her hands to the king unless that girl could become the real queen, with her son as heir to the throne. So his son, named *Bhīṣma*,

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renounced his claims to the throne and also took a vow not to marry, so that there would be no possibility of any rival to the throne when the newly married wife would have a son. Such a son was born, named *Vicitravīrya*, who became king in due course. But he died young without a son born to him. His mother, who was also the mother of *Veda Vyāsa*, asked *Veda Vyāsa* to beget children by the two queens who were his sisters-in-law. In one queen was born through his union a son named *Pāṇḍu*. *Dhrtarāṣṭra* was blind and so when the sons came of age, the younger son *Pāṇḍu* became the king. *Pāṇḍu* had five sons (called *Pāṇḍavas* representing goodness) and *Dhṛtarāṣṭra* had a hundred sons (called *Kauravas* representing evil). *Yudhiṣṭhira* was the eldest son of *Pāṇḍu* and *Suyodhana* was the eldest son of *Dhṛtarāṣṭra*. "Here the five sons of *Pāṇḍu* called *Pāṇḍavas* represent a pedigree of goodness while the hundred sons of *Dharṭarāṣṭra* called *Kauravas* represent a pedigree of evil. In another pedigree mentioned by Raja (1962, p.89) gods and demons were descendants of the same ancestor, the gods being the sons of one mother and the demons being the sons of her rival. It is advisable and instructive to compare these pedigrees with the pedigrees of modern Genetics breiefly described by Storer and Usinger (1957, p. 175)—"The 'Jukes' family, studied by Dugdale and Estabrook is one of bad pedigree that was traced through several generations. From the marriage of a shiftless farmer's son and a prostitute, a total of 2,094 descendants was identified; these included 299 paupers, 118 criminals, 378 prostitutes, and 86 brothel-keepers. There was a general record of intemperance and illegitimate births, and half the total were feeble-minded. The 'Kallikak' family, analysed by Goddard, presented an even more interesting situation. Martin Kallikak had a son by a feeble-minded girl, then married into a respectable family, and produced several children whose descendants became worthy members of the society. The illegitimate feeble-minded son, however, sired a degenerate line comparable with that of Jukes family."

On the transmission of specific characters and on the question as to why the offspring is the same as the parental organism, that is, 'why like begets like', Caraka and Suśruta say: "All organs are potentially present at the same time in the fertilised ovum and unfold in a certain order. As the sprouting bamboo seed contains in miniature the entire structure of the bamboo, as the mango blossom contains the stone, pulp and fibres which appear separated and distinct in the ripe fruit, but through excessive minuteness are indistinguishable in the blossom, even such is the case with man." (Talukdar, 1963). It goes without saying that the seeds of modern Genetics had already been sown in the ancient Sanskrit texts.

Keswani (1963) deals exhaustively with the knowledge concerning reproduction, human Embryology and Genetics as found in the early Sanskrit works. According to him the numerous extant scriptures and other writings of purely philosophical and scientific nature are replete with the ideas that our ancient scholars had regarding generation, reproduction, Genetics and heredity and human developmental Anatomy. The principal works mentioned by him containing these ideas are: the *Vedas*, *Upaniṣads (Chāndogya*, *Bṛhadāraṇyaka*, *Garbha*, etc.), *Anugītā*, *Śatapatha Brāhmaṇa*, *Manu Smṛti*, *Samhitās* of Ātreya, Suśruta, Caraka and Vāgbhaṭa, *Purāṇas* (*Padma*, *Viṣṇu*, etc.) and some Tāntric texts. He deals with the ideas of the physical nature of the primal seed, of conception and menstruation, and then remarks that

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in the works of the Sanskrit writers mentioned "the various developmental stages of the human embryo from the time of its fertilisation until full term have been so well described that one is amazed at the acuity of their observation. The only inference one can therefore draw is that they must have had some sort of aid of optical instruments to be able to describe even the microscopic appearance of the early zygote and must have studied embryo-genesis in experimental animals, or that it was their routine practice to examine and even dissect the abortus and the stillborn." Keswani then examines in detail the ideas of the Sanskrit works about organogenesis, histogenesis, formation of the placenta, determination and prediction of sex, eugenics and genetic transmission of characteristics. Some of these ideas are fairly comparable with the ideas of modern Zoology. For example, according to Suśruta, as stated in *Garbha Upaniṣad* also, "a seed divided into two by the deranged *Vāyu* within the cavity of the uterus gives rise to the birth of twins." The process of production of identical twins in the modern Genetics is exactly the same (Storer and Usinger, 1957, page 137).

Bose (1963) refers to the fact that Manu "believed firmly in the hereditary transmissibility of character. The quotations from the two chapters of *Manusamhitā* translated by Sir William Toner clearly indicate the nature of the theory of heredity: Chapters IX and X discuss the influence of both parents in the determination of the characters of the offspring."

Chaudhary (1967) deals with the knowledge concerning Embryology of the human body as contained in th *Yājñavalkya Smṛti* in which according to him there is a description of the development of the human body from its embryonic to the full-grown stage in all its parts.

Majumdar (1968) mentions that "Lakṣmīdhara, the minister of the Ghadvala King Govindacandra, grandfather of Jayacandara, quotes in his *Gṛhastha Kāṇḍa* of the *Kṛtyakalpataru* (c. 1120 A.D.) twelve verses from *Nārada* explaining fourteen kinds of sexual aberrations and impotence and states that, if unwittingly one has given in marriage his daughter to such a person, he should get his son-in-law treated medically and, if the treatment proves ineffective, the girl should be married to another". The ideas contained in this reference are good contributions to the science of Eugenics.

According to Mishra (1968) the *Agni Purāṇa* gives an account of the process of conception, monthwise development of the Embryology and the factors responsible for the development of the various organs of the human body.

ECOLOGY

Ecology is the study of the relations of animals to their environment. This environment may be physical consisting of abiotic factors like temperature, light, moisture, air, etc. or it may be biotic environment consisting of animals and plants influencing the life of other animals. Sanskrit literature contributes a lot to this branch of Zoology.

"The *Ṛgveda* is essentially Nature poetry, dealing with certain powers in Nature;" (Raja, 1962, page 21); "for, the gods who are invoked are nearly all per-

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sonifications of the phenomena of Nature." (Macdonell 1899, page 53). Variations in the movement of the sun cause variations in the intensity of light resulting in dawn, day, dusk, and night. Sun god or *Sūrya* is one of the solar deities who measures the days, prolongs life and drives away disease; all beings depend on *Sūrya* and so he is called "all-creating" (Macdonell 1899, page 64). This may be interpreted to mean that the sun provides energy for photosynthesis resulting in the manufactures of initial food essential for life. *Uṣas*, the goddess of dawn in *Ṛgveda*, makes the birds fly up. When *Uṣas* shines forth, the birds fly up from their nests and men seek nourishment " (Macdonell 1899, page 67). *Savitṛ* is another solar deity of the *Ṛgveda* "not infrequently connected with the evening being in one hymn (ii.38) extolled as the setting sun"; and its effect on animal-life has been described as just the opposite to that of *Uṣas* in that the birds seek their nests and the cattle their shed (Macdonell 1899, pp. 64, 65). Night is represented by the goddess *Rātrī* in hymn X.127 of the *Ṛgveda* and its effect on animal-life is that at her approach the birds seek their nests upon the trees, the active beasts and flying birds, as well as hungry hawks (meaning probably the active hawks preying for food) come to rest and stop their activity; while the male and female wolves become active and may prove harmful to men (Macdonell 1899). In hymn V. 83 of the *Ṛgveda*, there is a description of the activity of *Parjanya*, the god of rain. Macdonell (1899, page 76) gives an English rendering of this hymn from which the modifying effect of the rain on biotic and abiotic environment can be analysed somewhat like this: (*i*) under a strong rain storm the trees fall to the earth; (*ii*) lions roar and the roar reverberates from far off places; (*iii*) the winds blow forth; (*iv*) the lightening flashes fall to the earth; (*v*) the herbs shoot up; (*vi*) nourishment in abundance springs for all the world at a time when *Parjanya* (rain) quickens the earth with seed; (*vii*) there is thunder and there is roar; (*viii*) "the vital germ deposit" meaning that the environment is rich with reproduction and new life; (*ix*) the abundance of moisture (that is, water) makes the heights and hollows equal, meaning that during very heavy rains, the rivers and streams are in spate resulting in terrible floods when even the mountains may be so much under water that there is left no distinction between them and the low-lying land. The whole description beautifully depicts the inter-relationship of different environmental factors. *Agni* is fire-god of *Ṛgveda* and its rage in the forests has a terrible effect on forest-life and on the environment of the forests, a few facts about which as gathered from Macdonell (1899, page 78) are worth mentioning: (*i*) driven by the wind the fire rushes through the wood; (*ii*) (*ii*) *Agni* invades the forests and shears the hairs off the earth, shaving it as a barber a beard, meaning that the forest-fires destroy all plant and animal-life; (*iii*) the flames are like the roaring waves of the sea bellowing like a bull and the birds are terrified at this noise as well as on the sight of the rising grass-devouring sparks.

The *Ṛtusamhāra* of Kālidāsa is a monographic type of work on the biology of the seasons. The year has been divided into six seasons: (1) summer, (2) rains, (3) autumn, (4) cold, (5) dew, and (6) spring. There are lively descriptions of animal and plant-life and also of abiotic conditions in each of these seasons. Not only in *Ṛtusamhāra* but also in other works of Kālidāsa there lies scattered valuable information about the effect of seasons on animal-life. Examples of facts concerning animal-life in summer gathered from the works of Kālidāsa, specially from the *Ṛtusamhāra* will illustrate the sharp and scientific observations of this great poet. They are as follows:

All life in summer is dull. Wild animals appear thirsty with their tongues dry. They run to forests in distant horizon taking the blue sky to be water to quench their thirst. Wild boars dig out earth with their long snouts as if they want to go under the ground surface to avoid heat. Elephants collect in ponds, lakes or rivers to drink water and to cool themselves; and consequently fish in great numbers are trampled under their feet so that the fish-population of these places is much reduced, as well as the water-birds run away from there out of fear. Forest-fires so common in summer put a great stress upon the wild life. Buffaloes pour out foam and saliva from their mouths with open mouths as well as with their red tongues out, they come out of the mountain-caves and progress towards water to quench their thirst. Birds sitting on leafless trees are panting for breath. Sad monkeys in large numbers enter mountain-caves to take shelter against heat. Beasts roam here and there in search of water which at most of the places dries up. Perplexed by heat aggressive animals lose their aggression; for example, snakes do not harm their enemies, the frogs which come out of the ponds and take shelter under the shed of the hoods of thirsty snakes without any fear; peacocks, the great enemies of the snakes, have now become friends to them in the sense that a snake under the torture of heat hissing and with its mouth bent downwards moves without fear under the shade provided by the body of the peacock which, instead of doing any harm to the snake, puts its neck in the coils of the snake to protect its mouth against the burning sun. Lions or tigers are panting for breath licking their lips with their tongues and are not in a mood to fight with the elephants standing nearby. The elephants with foams falling from their mouths wander here and there in search of water without any fear of lions; troubled and somewhat burnt with forest-fires, elephants, lions and oxen become friends, escape together from the flames and take rest together on the sands of the river-banks. These examples illustrate the important ecological phenomenon that in the face of a common enemy the deadliest enemies become friends. While most of the animal-life has been described as dull, activity, however, may be seen in some insects hovering round the blooming jasmine flowers in the evening, and in some aquatic birds like geese and cranes.

In a similar way Kālidāsa describes life in other seasons.

Some more descriptions of ecological importance found in the works of Kālidāsa are as follows:—

1. Life at sunset—*Kumārasambhava*, VIII. 30-39.
2. Fauna of a deserted place—*Raghuvaṃśa*, XVI. 12-22.
3. Regional descriptions : *i*) of a particular forest—*Raghuvaṃśa* IX. 51-74 *ii*) of a particular mountain—*Kumārasambhava*, I. 1-16.
4. Aerial survey of land and sea—In the 13th canto of *Raghuvaṃśa* Kālidāsa describes the journey of Rāma in his aerial car from Ceylon to Ayodhyā after his victory over Rāvaṇa. The car passes over the southern sea, Malaya mountains, Godāvarī, Citrakūṭa, Jamunā, Gaṅgā, and Sarayū. The fauna, flora, forests,

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mountains, rivers, lakes and sea-coast of this region as seen in the aerial view have been given a graphic description which is recognised as one of the best in Sanskrit literature. Some important observations in this aerial survey about fauna should provide interesting examples:

(*i*) Crocodiles are seen taking into their mouths fishes along with sea-water and then squirting out the streams of water through their nostrils after closing their mouths.

(*ii*) Snakes are seen lying in wavy posture along the sea-coast to breathe the coastal air.

(*iii*) There are red coral reefs along the coasts. When conches strike against the corals, their mouths are pierced and out of the resulting pain their movements are slowed.

(*iv*) Pearl mussels and pearls lie scattered on coastal sands.

(*v*) There are deer-herds in forests south of Malaya mountains.

(*vi*) There is an indication of the presence of peacocks on Malaya mountains and about their sweet songs when Rāma had been roaming there during his exile.

vii) The view has been vividly described about water-birds, as for example: the courtship between male and female *cakravāka*, the Brahmani duck, the swimming of the cranes on the waters of the rivers, the flights upwards of the cranes in characteristc formations etc.

The ninth act of the *Mālatīmādhava* of Bhavabhūti gives a regional description of the Vindhya range with its fauna and flora in their natural surroundings, and the seventh act of the *Mahāvīracarita* of the same poet represents the journey of Rāma in an aerial car from Ceylon all over the way to Ayodhyā (Macdonell, 1899, page 308). The descriptions in the works of Kālidāsa and in those of Bhavabhūti about Nature may be regarded as most scientific because these poets represented and described Nature as they observed her. In this connection the remarks of Raja (1962, pages 142 and 189) are worth quoting here:—

"In the matter of the description of Nature also, Kālidāsa presented what he felt in his heart while the later poets presented what they knew in their erudition. Nature had lost its life, though the beauty of Nature was retained; this beauty became what the poet knew from books and not from observing Nature."

"Bhavabhūti is also a master in the description of Nature, and it is the grand aspect of Nature that he loves most. In the various dramas sketched above there are few in which there is anything that can be called Nature. It is only in Kālidāsa that there is a dominance of Nature, and this is true also of the epic poems. What Nature there is in the later epics are descriptions of Nature that the poets knew in their erudition and not what they felt in their heart. After Kālidāsa we come here to another poet who has known Nature in his heart and who has realised and enjoyed the beauties of Nature, and who has been able to express such beauties of Nature in poetic language. He loved Nature as did Kālidāsa and he wrote poetry because he felt and realised the beauties of Nature; he was in communion with Nature."

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In *Suśruta Samhitā* there is the idea of the classification of habitats and a correlation between the form of fishes and their respective habitats, and it is further remarkable that these correlations were even explained against the background of environmental factors (Hora, 1951a). Similar ideas of classification based on ecology are also found in *Chāndogya Upaniṣad* (Rao, 1957).

ORIGIN AND EVOLUTION OF LIFE

Valuable information lies burried in Sanskrit literature on the philosophy of Zoology concerning origin and evolution of life. The works in which it is contained are:—*Ṛgveda; Atharvaveda; Bṛhadāraṇyaka Upaniṣad; Śatapatha Brāhmaṇa; Purāṇas; Mahābhārata; Manusmṛti; Caraka Samhitā;* and works on *Sāṅkhya, Yoga, Vaiśeṣika* and *Nyāya* systems of philosophy. The subject has been discussed by a number of writers: Macdonell (1899), Seal (1902), Chakravarti (1951), Majumdar (1953), Hora (1955), Ghosal (1957), Sen (1963), Keswani (1963), Ali (1963), Subbarayappa (1966), and Rensch (1966). Ali (1963) remarks that "ideas on the evolution of life on this planet have been brought out by the ancients in very interesting ways, and what is more surprising, in consonance with modern views on the subject."

TAXONOMY

Taxonomy or Systematic Zoology is the study of the classification of animals and of its principles. Classifications of animals have been attempted in *Ṛgveda, Atharvaveda, Chāndogya Upaniṣad, Manusmṛti,* and in the works of Suśruta, Patañjali, Praśastapāda and Caraka. Most of these classifications have been artificial as based on habits, habitats, environmental factors, and reproduction. A classification which may be called somewhat natural, as to some extent based on structural characters, is that found in the Jaina work *Tattvārthādhigama* of Umāsvāti thought to be of A.D. 40 but now established to belong to 135 B.C. (Keswani, 1963).

Rao (1957) and Keswani (1963) have discussed all these classifications in detail.

ECONOMIC ZOOLOGY

Indications are there that throughout Sanskrit literature animals have been regarded as both useful and harmful. Some important information about this economic aspect is considered here.

Usefulness:

Food—Milk and butter obtained from cows as well as flesh of bull, buffalo, horse, boar and of other animals sacrificed at ceremonial occasions, are the articles of food mentioned in *Ṛgveda* (Macdonell, 1899, pages 126, 139). Fish was regarded as an important article of food and the information about fish as food in Sanskrit works has been very well brought out by Hora (1948b, 1950, and 1951a, b, c, d). In addition to fish, wild beasts, birds, elephants and tigers have been recommended during famine to be used as food, in Kauṭilya's *Arthaśāstra* (Hora, 1948b).

Sacrifice—According to Rao (1957) over 50 species of animals of all classes, big and small, are mentioned in the *Vedic* texts as being fit for sacrifice at different ceremonial occasions, and amongst these are included frogs, serpents and other reptiles, birds, bats, carnivorous and herbivorous mammals including monkeys, even bees and other kinds of insects.

Ride and transport—According to Raja (1962), the *Vedas* and *Sanskrit Classics* speak of certain animals used by gods for riding in their vehicles, the chariots. Some examples are as follows:—

Name of god	*Animal used*
Aśvins	.. donkey
Viṣṇu	.. kite
Śiva	.. bull
Durgā	.. tiger
Brahmā	.. swan
Gaṇeśa	.. rat
Subrahmaṇya	.. peacock

According to Macdonell (1899, pages 126, 127), bulls and oxen have been mentioned in *Ṛgveda* as being used for drawing carts, and horses in drawing the war cars and in chariot-races.

Owing probably to the military needs of horses and elephants the science of these two animals appears to have been very well developed in India and there are some Sanskrit works of uncertain dates on the knowledge about these two animals. "The *Hastyāyurveda* of uncertain date and the *Mātaṅgalīlā* of Nārāyaṇa are the two known works on the science of elephants. The *Aśvāyurveda* of Gaṇa, the *Aśvavaidyaka* of Jayadatta and of Dīpaṅkara, the *Yogamañjarī* of Vardhamāna and the *Aśvacikitsā* of Nakula are extant works on the science of horses." (Sastri, 1960, page 172).

Hunting, tracking and guarding—In *Ṛgveda* has been mentioned the use of dogs for the purpose of hunting, guarding and tracking the cattle and keeping watch at night (Macdonell, 1899, page 176). In hymn X.108 of the *Ṛgveda*, *Saramā*, the famous bitch of the gods, the messenger of Indra, tracks the stolen cows (Macdonell, 1899. page 100).

As messengers and emissaries—In addition to the bitch *Saramā* as messenger of Indra mentioned above her two sons, the dogs, as well as animals like owl and pigeon are occasionally referred to as regular messengers of Yama in the *Ṛgveda* (Macdonell 1899, page 98). Hanumān, the monkey-chief, as messenger from Rāma to Sītā, is known to everybody. Sastri (1960) remarks that in Sanskrit literature there are about 50 *Dūtakāvyas* and that in addition to other objects, beasts and birds have been chosen as messengers for imaginary journeys over different places in India.

According to Hora (1948*b*), a peculiar use of animals for a like function is mentioned in Kauṭilya's *Arthaśāstra*, Book XIII, Chapter V dealing with the operation of a siege. "Kauṭilya advises the reduction of the enemy before the commencement of the siege, and among a large number of other measures suggests:

'A splinter of fire kept in the body of a dried fish may be caused to be carried by a monkey or a crow, or any other bird (to the thatched roofs of the houses)

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(page 468)'". In explanation Hora further adds that "a splinter of fire kept in the body of dried fish is not likely to go out since there is always a certain amount of body oil that will come out from dried fish when heated and this will keep the splinter alive."

There have been reports, according to Aslam (1971), that a large number of trained monkeys have helped the Indian army and Mukti Bahini in Bangla Desh against the occupation forces of West Pakistan. He adds that the people should not be astonished to hear this as he gives in detail the story of "All Alone", a tiny pigeon which played a key role in the defeat of Hitler in the last war by bringing vital information from occupied Europe to Britain against all odds of the trained hawks of German troops. When such is the case in modern history, it is really no wonder if the use of animals in war for purposes like those mentioned above are found in Sanskrit literature.

As ingredients in smoke mixtures against enemies—Hora (1948b) mentions fish, certain insects (as *indragopa*, the cochineal insect) and hoofs and horns of goats as ingredients of mixtures to produce such a smoke that destroys animal-life as far as it is carried off by the wind, or may cause blindness. Such mixtures according to him are mentioned in Kauṭilya's *Arthośāstra*.

In Agriculture—Use of bulls for drawing the plough is mentioned in the *Vedas* (Macdonell, 1899, page 140) and in the *Kṛṣi Pārāśara* (Rai Chaudhuri, 1963).

In Medicine Hymn IX. 112 of the *Ṛgveda* mentions the use of leeches to cure fracture (Macdonell, 1899, page 108). The use of animal tissues to fasten the edges of flaps of skin in plastic surgery and the use of dead animals to demonstrate venesection of blood vessels to the medical students is mentioned in *Suśruta Saṃhitā;* while the works of Caraka and Suśruta embrace a number of animal substances used as drugs, such as : milk from humans, cows, elephants, camels, goats and mares; butter, honey, meat, bile, blood, and urine, horns, claws and nails (Misra and Pandeya, 1963). Dash (1968) gives a number of animal-products mentioned in Sanskrit literature for the use of sterilistion and contraception; examples are: the bone of water fowl, the tooth of a boar, hair from the trunk of an elephant and from the tail of a horse, goat's milk, egg of sparrow, dung of elephants, blood of rabbit, etc. Mitra (1968) refers to the fact that information on the use of animals to test the properties of medicinal plants and drugs and also to test whether a particular food is poisonous or not, lies scattered in *Atharvaveda* and in the works of Caraka and Suśruta. He adds that the animals used for this purpose were: boars, mongeese, snakes, goats, sheep, cows, dogs, *cakoras* (partridges), cuckoos, herons, peacocks, parrots, monkeys, deer, *etc.* Further he says that the "people in Ancient India were well aware of the germ-free animals as in the present time, hence the association with goat and the use of its meat was advocated in the cases of tuberculosis".

Miscellaneous uses—The uses of sheep for wool, of horns for poisoned tips of arrows and of skins of animals for various purposes are mentioned in the *Ṛgveda* (Macdonell, 1899, pages 138-141). Lac, honey and silk as insect-products are referred to in the works of Kālidāsa (Gupta, 1963). Besides this Rao (1957) has mentioned a number of economic uses for various animal-products.

Harmfulness

Atharvaveda speaks of noxious animals, injurious insects, poisonous insects and their bites; while the *Gṛhya Sūtras* make mention of an offering made to serpents at the beginning of rains when the use of raised bed is enjoined owing to the danger from snakes at that time (Macdonell, 1899, page 155. 165, 215). *Atharvaveda* refers to the disease-producing worms, to insects as crop-pests and also to the dangers from wild animals (Raja 1962, page 27). *Damśa* (probably a horsefly or gadfly), ants and locusts are mentioned as harmful insects in the works of Kālidāsa (Gupta, 1963).

CONCLUSION

From what has been discussed above it is clear that the contributions of Sanskrit literature to each of the branches mentioned above are significant and meaningful. The information given above is just a humble peep into the great window. The field is still virgin to a good extent and is full of great promises for prospective workers.

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SOME ASPECTS OF SANSKRIT TEXTS DEALING WITH CHEMICAL, IATRO-CHEMICAL AND BIOLOGICAL IDEAS

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The record of ancient and medieval Indian scientific concepts and ideas is found mainly in the sacerdotal texts, philosophical compendia and secular writings, particularly those relating to practical life. These, however, are general sources in the sense that these are not exclusively scientific treatises. The specific sources are the manuals on particular sciences. These are, however, not original contributions, for their scientific ideas and concepts can be traced back in the earlier and general descriptions. The discourses are admittedly more coherent and made upto date on some points with additions of new and improved knowledge.

The specific sources of ideas on Indian chemistry are the *Rasaśāstras* (8th or 9th century A.D.), the repositories of vast mass of chemical information. The value of the *Raasaśāstras* lies in one of its basic theme, the principle of prolongation and immortalization of human life. Notably this concern may be traced in all the important Sanskrit texts from the *Vedas* (c. 1500 B.C.) to the *Tantras* (c.5th or 6th century A.D.).

At a later point, the discussion on the assessment of scientific contributions of the *Rasaśāstras* will be attempted.

The biological ideas relating to plant and animal-life are contained in the special works related to their life, like *Vṛkṣāyurveda* (science of plant-life), *Aśvāyurveda* or *Aśvaśāstra*, *Hastyāyurveda* or *Gajaśāstra* (works on healing, training and breeds of horse and elephant), and *Mṛga-pakṣi-śāstra* (13ht century A.D.—science of life of beast and bird). The *Vedic* literature, philosophical compendium, the Āyurvedic treatises, Epics and the *Purāṇas* are relevant records of more significance. For example, the questions regarding life and composition of organic body, are more illuminatively dealt with in the general works than in the specific ones. The specifically biological treatises appear to have no basic and substantial concern like that of the works on chemical ideas. Most of them are devoted to the discussion of healing of the plant and animal-life which are often a subject of discussion in the *Purāṇas* (like *Agni Purāṇa* and *Garuḍa Purāṇa*). Among the different special sources, the *Vṛkṣāyurveda* of Parāśara (c. 1st century B.C. or 1st Century A.D.) must be mentioned for its presentation of coherent ideas about the germination, morphology, physiology, ecology, taxonomy, etc., of the plant world.

The exposition of early biological science will consider the contribution of general works in the area of study of plants as living objects, classification of animals according to the mode of reproduction and conception and development of human foetus.

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A. *Chemical ideas*

Indian chemical ideas as found in general treatises related mainly to the knowledge of metals[1] and metallurgy[2], conception about the constitution and properties of matter[3], preparations of fermented liquors[4], alkalis[5], metallic salt,[6] cosmetics and perfumes, *vajralepa*[8], (cement), and so on. There are no doubt the valuable evidence of early Indian chemical theory and practice. But the appearance of the *Rasaśāstra* texts is a land-mark in the history of Sanskrit literature to the contribution of chemical ideas and practices based on religio-philosophical speculation and experimentation.

The keynote of these particular treatises is to devise the way to immortality and rejuvenation, and to the transmutation of base metals into gold by means of mercury[9]. These treatises, flourishing between 9th and 10th centuries A.D., which owed their origin to the esoterism and mysticism of the Tantras and its practitioners. According to Tāntric experience, attainment of spiritual ascendence in living state depends on a perfect body, not subject to death and decay. Thus *rasa* (any chemical substance, especially mercury) came to be considered as one of the devices to acquire a perfect body (*Siddha deha, Sthira deha*)[10]. At this point one must acknowledge the contribution of general works and Āyurvedic treatises (c.500 B.C.). The idea of *rasa* not in the sense of chemical substance but in the sense of fluid as vitalizer of human body can be traced in the *Yajurveda* (c. 1200 B.C.)[11]. In the *Ṛgveda*, 1(1500 B.C.) the Soma (*Sacrostema viminalis*) which conveys the sense of the juice, *viz.*, *rasa* of the plant, is highly cextolled as the vehicle to immortality[12]. In the Āyurvedic treatises *rasa* stands for body fluid. *Rasāyana* (literally means "path or course of *Rasa* or body fluid") in these treatises aims at the strengthening and nourishing of the body fluid by means of pure herbal drugs or herbo-metallic drugs which act as vitalizers or elixir. The idea of vitalizing

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[1] *Ṛgveda* i.85.9; 88.5; 167.3; ii.33.9; v.54. 15; 57.1; 60.4; viii.7. 27-32, etc.

[2] *Arthaśāstra* Ed. and trans. into English by R. P. Kangle Pts. I, II. Bombay University, 1960, 1963. 2. 12. 8-9; 13. 5-15; 47-49.

[3] See (i) B. N. Seal—*Positive Sciences of the Ancient Hindus* 1958, pp. 24-121;
(ii) B. V. Subbarayappa—"On Indian Atomism", *Bulletin of National Institute of Sciences of India*, No. 21, 1963, pp. 118-129.
(iii) P. Ray—"Theory of Chemical Combination in Ancient Indian Philosophy" *Indian Journal of History of Science*, 1 (1) 1966, pp. 1-14.

[4] *Arthaśāstra*, 2, 25.

[5] *Suśruta-Samhitā* Ed. by Nripendrnath Sengupta and Balai Ch. Sengupta with the commentary of *Nibandhasamgraha* by Ḍallana. *Sūtra* 11.

[6] *Ibid*. *Cikitsā*, 10, 11-14.

[7] *Bṛhat Samhitā* (Ed. by V. S. Sastri & V. M. Ramakrishnan Bhat, Bangalore, 1947) 77 1-17.

[8] *Ibid*. 57, 1-8.

[9] & 16. *Rasārnava* Ed. by P. C. Ray & Harischandra Kaviratna *Bib. Indica*. (Calcutta 1910) i. 20-21; xiv. 48.
Rasahṛdaya (Ed. by Jadavji Tricumji Acharya, Ayurvediya Granthamala, Vol. I, i. 13.

[10] *Rasahṛdaya* i. 10-13.

[11] *Vājasaneyi Samhitā*, xi. 50, 52; xxxvi. 14-16.

[12] *Ṛgveda*, viii. 48. 3-4.

[13] *Suśruta-Samhitā*, *Śārīra*, 9, 12.

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human body, originating in the Vedic literarture and elaborated in the Āyurvedic texts, took a perfect and concrete shape in the *Rasaśāstra* where *Rasa* stands for mercury. The term *Rasa* is given to mercury on account of its semi-fluid character and its presumed thereapeautical action on the juice or fluid of body (*rasanāt sarvadhātūnām rasa ityabhidhīyate jarāmṛtyunāśāyo rasayate vā raso mataḥ*).[14]

Not only on human body, action of mercury on metals which are supposed to be similarly composed of five elements on the basis of the elemental body of mercury (*pañcabhūtātmakah sūtah*[15]), was conceived by the *Rasavādins* (i.e., the alchemists or the chemical practitioners[16]). This led to the search for powder of projection (*rasa*), and as a result large scale experiments on the properties of plants, metals, minerals, and products of animal body, were carried on for bringing out the desired element. Mercury had to undergo eighteen processes before being used on the metallic body and on human body with a view to bring transformation. The eighteen processes as laid down in these texts are: *svedana* (steaming or heating using a water bath), *mardana* (grinding), *mūrchana* (swooning or making mercury lose its form), *Utthāpana* (revival of form), *pātana* (sublimation or distillation), *rodhana* (potentiation), *niyamana* (restraining), *sandīpana* (stimulation or kindling), *gaganabhakṣaṇa* (consumption of 'essence' of mica), *cāraṇa* (amalgamation), *garbhadruti* liquefaction - internal), *bāhyadruti* (liquefaction - external), *jāraṇa* (digestion or assimilation), *rañjana* (colouration), *sarana* (blending or preparation for transformation), *saṅkramaṇa* (acquiring power of transformation), *vedhana* (actual transformation or transmutation), and *sevana* (becoming fit for internal use). [16a].

The idea of transmutation of inferior metals into the superior one with the help of *rasa*, seems to be not indigenous to the *Rasaśāstra*. The *Arthaśāstra* (c. 4th century A.D.) refers to gold prepared from transmutation of base metals by means of *rasa* (*rasaviddham suvarṇam*). On the authority of the *Arthaśāstra*[18], Kangle[19] mentions *rasa* as 'liquid gold' as it has the power of transmuting base metals into gold. The meaning of *rasa* is confusing as the evidence of *rasa* in the sense of mercuy is found to occur in the *Rāmāyaṇa*[20] (c. 200 B.C. - 200 A.D.). In this connection it is essential to refer to one verse from the *Atharvaveda*[21] (c. 1000 B.C.) which mentions the threefold origin of gold. One of the origins is stated to be "Soma when injured" (*Somasyaikam himsitasya parāpatat.*) The verse can be interpreted in this manner. *Soma* viz., *candra*, i.e. moon or moon-god stands for two metals gold and silver[22]; *himsita*, literally means injured or killed, which appears to convey the sense of "perforating" or piercing" *vidh*, technically tansmutation. On the basis of this interpretation the verse might be taken as conveying the sense of "gold prepared from the transmutation of silver."

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[14] *Rasaratnasamuccaya* Ed. by Mahadeva Cimnaji Apte, Anandasrama Skt. Series, 1892 (Saka) i.77.

[15] *Rasārṇava*, xii.83.

[17] *Arthaśāstra*, 2, 13.3.

[18] *Ibid*, 2, 12.5.

[19] *Ibid* (Pt. II of Kangle) p. 127. for N. 3.

[20] *Rāmāyaṇa* (Ed. by Hemachandra Bhattacharya, Calcutta, 1884) II. 94. 6.

[21] *Atharvaveda*, v.28.6.

[22] *Ṛgveda*, X. 107.7. (See Sāyana's interpretation of the term *candra* as *rajata*).

Rasaśāstra, based on philosophy of mercury, is a general term including both alchemical and iatro-chemical (*i.e.* medicinal chemistry) treatises. In fact, alchemy evolved into iatro-chemistry. The former is devoted to the search after the *rasāyana* viz., *elixir vitae* and the powder of projection (*Rasa*). As an adjunct to the Tantras the alchemical treatises are characterized by their queer ideas about the enchanting and magical power of the *siddhidravyas* consisting of some mercurial preparations[23] and natural substances[24]. The chemical operations are blended here with tāntric rites[25]. The iatro-chemical texts, the origin of which are ascribed to the period between 1300 and 1500 A.D., concentrates mainly upon the use of mercury and other medicaments as accessories in medicine to make the body immune from decay and disease (*rasānāmatha siddhānām cikitsārthopayoginām*). The fantastic and extravagant ideas relating to the power of mercury had subsided into the more practical and tangible.[27]

A large number of *Rasaśāstra* texts attributed to different authorship emerged from 9th to 18th century A.D. The *Rasahṛdaya* of Govinda Bhagavat (c. 8th century A.D.), *Rasaratnākara* of Siddha Nāgārjuna (c. 9th century A.D.) and *Rasārṇava* (c. 12th century A.D.) are exclusively alchemical texts. The others of this period combine discussions on both alchemy and iatro-chemistry. These provide systematic treatment of earlier ideas with additional knowledge and practice relating to the mercurial compounds and a host of other substances. But they are to some extent stereotyped.

The *Rasaśāstra* texts of general character *i.e.*, not concentrating on the particular chemical operation, more or less contain the same contents such as praise of mercury in the introductory portions, explanations of the origin of mica, sulphur and few other substances also in a mythical way, the eight *mahārasas*, the eight *uparasas*, the eight *dhātus* or metallic substances and also precious stones, elaborate processes for purifying and processing of the alchemical substances, use of herbs and symbolical forms (*paribhāṣā*)[28].

The tāntric alchemical *Rasaśāstra* texts may be divided into two classes : (*i*) alchemical ideas forming part of certain tāntric texts and (ii) a systematic presentation of different facets of *Rasaśāstra*. To the former come the *Mātṛkābhedatantra*[29], *Rasārṇavakalpa*[30], ***Rasakalpa*[31], *Rasratnākara* and *Dhātukriyā* or ***Dhatumanjarī*[32] of the *Rudrayāmalatantra*. Among the three texts associated with the *Rudrayāmalatantra*, the *Rasārṇavakalba*[28] bears some characteristics of the *Rudrayāmalatantra*. The others

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23. *Rasārṇava*, xciii. 207-230.
24. *Rasārṇavakalpa* (Mss), Verses 610-626; 681-691.
25. *Rasārṇava* ii (entire chapter); *Rasārṇavakalpa* verses 230-233, 261-264, 298-300.
26. *Rasaratnasamuccaya* i. 8.
27. Ray, P. *History of Chemistry in Ancient and Medieval India*, Calcutta, 1956, p. 158.
28. Bose, D. M., Sen, S. N. and Subbarayappa, B. V., (Ed.) *Concise History of Sciences in India* Indian National Science Academy, New Delhi, 1971. Vide, 'Alchemy and Chemical Practice' p. 314.
29. Subbarayappa, V. B. and Roy, M. "*Mātṛkābheda tantraṃ and* its Alchemical Ideas" *Indian Journal of History of Science*, 3 (1), 1968, pp. 43-49.
30. Roy, M.—"*Rasārṇavakalpa* of the *Rudrayāmalatantra*" *Indian Journal of History of Science*, (2), pp. 137-142.
31 & 32. Roy, P. *Ibid*, pp. 156-157, 366-370, 414-446.

are purely chemical treatises. The important *Rasaśāstra* texts coming under the second category are **Rasahṛdaya* by Govinda Bhagavat, **Rasaratnākara* by Siddha Nāgārjuna, ***Rasārṇava* (author unknown), ***Rasendracūḍāmaṇi* by Somadeva, *Rasaratnasamuccaya* by Vāgbhaṭa, ***Rasaprakāśasudhākara* by Yaśodhara, *Rasaratnākara* by Nityanātha Siddha, *Rasarājalakṣhmī* by Rāmeśvara Bhaṭṭa, *Rasendracintāmaṇi* by Ḍhunḍukanātha, *Rasendracintāmaṇi* by Ramachandra Guha, *Rasasāra** by Govinda Ācārya, *Rasakaumudī* by Sarvajñacandra, *Rasabheṣajakalpa* by Sūrya Paṇḍita, *Rasasaṅketakalikā* by Cāmuṇḍa, *Lohapaddhati* by Sureśvara, *Kaṅkālīgrantha* by Nasirshah (Hindi), *Rasamuktāvalī* by Devanātha, *Rasapaddhati* by Bindu Paṇḍita, *Rasāmṛta* by Rāmeśvara, *Rasāmṛta* by Jayadeva, *Rasanakṣatramālikā* by Mathanasimha, *Rasacintāmaṇi* by Madanāntadeva, *Rasendrasārasaṃgraha* by Gopālakṛṣṇa Kavirāja, *Pāradayogaśāstra* by Śivarāma Yogin, *Rasaratnamālā* by Narasimha Kavirāja, *Rasamaṅgala* by Gahanānada Muni, *Rasarājaśaṅkara* by Rāmakṛṣṇa, *Rasakacchapuṭa* by Nāgeśa or Nagarjuna. There are few other works whose dates and authorship are not known to us. They are mostly devoted to the description of particular chemical substances and their treatments. Among these may be included : *Kailāsakārakaṃ*, *Gandhakakalpa*, *Pāradakalpa*, *Dhātumāraṇa*, *Dhāturatnamālā*, *Dhātuśuddhiprakaraṇa*, *Jāraṇamāraṇādi*, *Tāmrabhasmabheda*, *Yantroddhāra*, *Sūtapradīpikā*, *Rasadrutiprakaraṇa*, *Rasavaiśeṣikaṃ*, *Rāsadiyogagrantha*, *Rasagrantha*, *Rasaheman or Kaṅkālīyarasaheman*?)**, *Rasanighaṇṭu* and *Rasarañjana*. Most of the treatises do not bear new knowledge. They are compilation works.

The *Rasaśāstras* as stated above are mines of chemical information. Discussion on the chemical ideas as laid down in-some of these texts in connection with different chemical operations will follow on the following points :

I. Processing of the alchemical substances.

II. Transmutation processes.

I. *Processings of alchemical substances :*

Natural substances, excluding the plants before being applied for an alchemical preparation, had to undergo several processes, like *śodhana* (purification), *Sattvpātana* (extraction of essence from mineral and metallic substances) and *mārana* (killing).

(i) *Śodhana* (purification) : This was the first proceesing of mercury *sūta*, *pārada*, *rasa*, etc., metals (*dhātus*) and minerals *mahārasas* and *uparasas* and gems *ratnas*. It is generally performed by heating *pācana*[33] or by maceration *bhāvanā*[34], or by steaming (*svedana*)[35], or by distillation or sublimation *pātana* of the substance to be processed. This performance was preceded by grinding the metals or minerals with suitable substances and followed by the immersion of the same in liquid substances, mostly plant juices and cow's urine.

The **mark against the works refers to Manuscripts which are yet to be edited and translated while the single *mark against the works indicates edition of Manuscripts which, however, are neither translated nor exhaustively studied. Their proper edition and translation will, in all likelihood, throw light on the history o' Indian science'.

33. & 40. *Rasaratnasamuccaya*, ii. 17-18;

34. *Rasārṇava*, vii. 7, 10, 17.

35. & 39. *Rasaratnasamuccaya*, ii. 67.

Processes for the purification of different substances :

Mercury : Mercury, pasted with copper undergoes distillation in three ways, *viz.*, upwards, downwards and oblique and is free from its impurities derived from lead and tin.[37]

Sulphur (*gandhaka*)[38] : The mouth of the vessel containing milk is tied with a piece of cloth over which is placed powdered sulphur. This is then covered with an earthen bowl which is heated from outside so that sulphur melts and drops gradually into milk.

Mica (*abhraka, gagana*) : Mica, heated seven times and immersed into sour gruel, or cow's urine, or decoction of three myrobalans, becomes free from all impurities.[39]

Vaikrānta (a precious stone having eight surfaces and six angles, probably tourmalline) : *Vaikrānta* is purified by boiling it with the decoction of *kulattha* (horse gram, *Dolichos biflorus*).[40]

Gems (*ratna*) : Gems are purified by the application of 'vapours' of a plant *Jayanti*[41].

Metals (*dhātus*) : All metals are purified by heating and immersing them in the juice of plants, like *Kumārī* (*Aloe indica*), *Brahmaśobhā* (*Herpestes monniera*)[42].

(ii) *Sattvapātana* (extraction of essence) : Pure matter from the minerals and metals were derived by treating them with prescribed substances and then subjected to heating in a closed crucible. Generally *rasaka* (Calamine) and *sasyaka* (green vitriol), the two minerals (*mahārasas*) were processed in the above manner for extracting from them tin-like and coppery essences.

Extraction of essence from 'rasaka' (Calamine) : *Rasaka* mixed with wool, lac, *pathyā* (*Chebulic myrobalan*) and borax and subjected to heating in a closed crucible, yields an essence having the appearance of tin[43]. The extracted essence is zinc[44].

Extraction of essence of sasyaka: *Sasyaka* (*blue vitriol*) and one-fourth its weight of borax soaked in the oil pressed from the seeds of *karañja* (*Pongania glabra*) for one day only and then placed in a covered crucible, is subjected to heating in charcoal fire. By this process it yields an essence of the beautiful apearance of coccinella insect.[45] *The essence which is obtained is copper*[46].

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36. & 37. *Rasārṇava* x. 55; *Rasahṛdaya* ii. 8.
38. *Rasaratnasamuccaya* iii. 24.25.
41. *Rasaratnasamuccaya* iv. 60.
42. *Rasārṇavakalpa*, (Ms.) V. 467.
43. *Rasārṇava*, vii. 37-38.
44. Ray, P. *Ibid*, p. 138.
45. *Rasārṇava*, vii. 41-44.
46. Ray, P. *Ibid*, p. 138.

Extraction of essence from 'darada' (cinnabar) : *Darada*, roasted three days with cow-flesh, buffalo-urine, curd and oil of Sesamum, macerated in bile of peacock and distilled in *pātana* apparatus, yields an essence in the form of 'mercury'.[47]

(iii) *Māraṇa* (killing) : Killing was an important treatment performed for using the substances for medical compounds. The general process for bringing out this effect was rubbing, or smearing of the mercury and metals, etc., with prescribed drugs and mineral substances and then subjecting it to heating. For the killing of mercury, the latter admixed with prescribed substances is subjected to heating in a closed crucible[48], or to distillation and sublimation[49], or to boiling in steam by being kept in the bulbous root[50]. Instead of heating, mercury kept inside the bulbous root was deposited in heaps of paddy[51].

Killing of Mercury: (*a*) Mercury subjected to heating by being treated with a mixture of a number of plant-products, green vitriol (*sasyaka*), alum, salt and borax, is killed instantly[52]. This mercurial product is known as *śvetabhasma* or *karpūrarasa, viz.*, calomal[53].

(*b*) Mercury, admixed with killed gold, one-fourth of weight of mercury and sulphur, is made into a ball. This ball with sulphur of equal weight, is roasted in a crucible. Mercury thus treated is afterwards killed with six times its weight of sulphur[54].

This mercurial preparation is a potent medicine, and is otherwise known *makaradhvaja* or *rasasindūra*.

Some important processes associated with the different treatment of mercury, metals, etc.:

(*a*) *svedana* (steaming) : This was performed mostly in *dolāyantra* and *svedayantra*.

Dolāyantra : A pot is half filled with a liquid. A rod is placed across its mouth from which the substance is suspended by being tied in a piece of cloth. The liquid is allowed to boil and the substance is heated by its vapour.[55]

Svedanīyantra : A pot is filled with boiling water. The mouth of the pot is tied with a piece of cloth. The substance to be steamed is placed on it, and a second pot is arranged in an inverted position over the rim of the first.[56]

(*b*) *Pātana* (sublimation or distillation): This processing was generally carried on in the *pātanayantra*.

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[47] *Rasārṇava*, vii.48-49.

[48] *Rasaratnasamuccaya*, xi.109.

[49] *Ibid*. xi.109.

[50] *Ibid*. xi.115.

[51] *Rasārṇavakalpa* (Ms.) verses 157-158.

[52] *Rasārṇava*, xi.24.

[53] Ray, P. *Ibid*, p. 139.

[54] *Rasaratnasamuccaya*, xi.72-73.

[55] *Rasārṇava*, iv.6-7.

[56] *Rasaratnasamuccaya*, ix.5.

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Pātanayantra : Two types of *pātanayantra* were used for this operation—one for sublimation upwards (*ūrdhva*) and downwards (*adhaḥ*) and the other for oblique (*tiryak*) sublimation.

(*a*) *Adhaḥ and ūrdhva Pātanayantra :* "It consists of two vessels. They are arranged in such a way that the neck of the one fits into that of the other. The junction of the neck is luted with a composition made of lime, sugar, rust of iron and buffalo's milk."

In case of *adhaḥpātana* "the bottom of the upper vessel is smeared with the substance to be distilled, the vapour or essence thereof condensing into the water of the lower one. Heat is applied on the top by means of burnt cow-dung cake."

Thus when the substance is smeared inside the bottom of the lower one, and heat is applied thereto it is called *ūrdhvapātana*[57].

(*b*) *Tiryakapātana* : "Two vessels are arranged. One is provided with a long tube, inserted in an inclined position and contains the substance to be sublimated. The tube of this vessel is made to enter into the interior of the other vessel as receiver. The mouths of the two vessels and the joints are anointed with clay Strong heat is then applied at the bottom of the vessel containing the substances. The other vessel is filled with cold water where the substance being sublimed is made to fall"[58].

II. *Transmutation process :*

One of the objects of the *Rasaśāstra* as stated above is to transmute base metals into gold and silver. The texts abound in a larger number of such recipes which mainly consist of mercurial compounds.

The process of transmutation was performed in five ways namely, *lepa*, i.e. smearing copper or silver foils with the potent paste of mercury, *kṣepa*, i.e., throwing mercury into molten copper or silver ; *kuntavedha* i.e., pouring processed mercury into metal to be transmuted ; *dhūmavedha* i.e., subjecting the base metal to the action of fumes of mercury; *śabdavedha* i.e. effecting transmutation by the 'impact' of mercury.

Some transmutation processes to prepare gold (*hemakriyā*) and silver (*tārakriyā*) from other metals are given below :

Lead into Gold : "Vitriol which is of the colour of the throat of the peacock, saffron, calamine, excreta of a young calf, the poisons, powdered citraka (*Plumbago zeylanica*), all in equal proportions are rubbed with acids and dried in the shade. The mass then admixed with honey, is smeared on a thin sheet of lead. When roasted in a crucible, lead is turned into gold."[60]

Silver into gold : "Golden pyrite (*mākṣika*) and salt ground with honey and clarified butter, become red like saffron. This is to undergo heating in *nāgapuṭa* (a type

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57. *Ibid*, ix. 6-8; *Rasaprakāśasudhākara* i. 39-43.
58. *Ibid*. ix. 48-50; *Rasaprakāśasudhākara* i. 44-46.
59. *Rasaprakāśasudhākara* i. 130-136.
60. *Rasarṇava*, xvii. 70-74.

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of prolonged heating). Equal quantity of copper and this roasted mass, admixed together, is smeared on the leaves of silver, which processed three times in this way, is turned into gold."[61].

Bell metal (*kāmsya*) into gold : " A compound of six metals which are killed with the help of plant substances producing red extract, bdellium, and fermented liquor are deposited in heaps of paddy for four months. Bell metal roasted with this mass is turned into gold."[62]

Tin into silver : " One *pala* of mercurial ash, two of tin powder, two of silver ash, five of *śaṅkhacūrṇa* (powder of conch), eight each of common salt and borax, rubbed together and pressed with the milky juice of *snuhī* (*Euphorbia nerifolia*) is to be roasted fourteen times. Then the whole mass is stirred with an iron rod and again heated in a crucible, and is turned into silver"[63].

The discussion on the chemical ideas as found in the *Rasaśāstras* will be incomplete if we do not describe the methods applied for testing the purity of metal and mineral.

Test of pure metal :

" A pure metal is that which when melted in a crucible, does not give off sparks (*visphulinga*), nor bubbles (*budbuda*), nor spurts, nor emits any sound, nor shows any line on the surface (*rekhāpaṭala*), but is tranquil like a gem."[64]

Test of pure śilājatu (bitumen) ;

" Bitumen, while coming in contact with fire, takes the form of *liṅga*, emits no smoke and is fused in water; it is then known as pure"[65].

B. *Biological ideas*

The concepts and ideas about Indian biology, as preserved in different literary records, appears to have started around two fundamental questions of origin of life and preservation of life principle. The former led to the study of living objects and the latter to the investigation of different natural substances for the search of medicaments. Among the two, the study of living object forms an important aspect of the general philosophical discourses on nature and existence of 'soul' and on the composition of organic body. The search for medicaments gave rise to the development of a particular type of treatise, namely *Āyurveda*, the science of life. Separate treatises were composed on human, plant and animal life. Of course the medical treatises like the *Caraka Samhitā* and the *Suśruta Samhitā*, are mainly concerned with human life. Put they also made significant references to plant and animal life. These flourished from the period of 500 B.C. Later on, specific works appeared on plant and animal life. The two known texts of plant life are the *Vṛkṣāyurveda* of

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61. & 63. *Rasārṇava* xvii. 33-34.
62. *Rasahṛdaya* xviii. 23.
64. *Rasārṇava*, iv. 52.
65. *Rasaprakāśasudhākara*, v. 95; *Rasaratnasamuccaya*, ii. 114.

Parāśara (c. 1st century B.C.—1st century A.D.) and *Vṛkṣāyurveda* of Śūrapāla (11th century A.D.

The treatises on animal life appeared not before than 10th century A.D. Most of the treatises on horse have derived their knowledge from the write-up of Śālihotra, the presumed preceptor of Indian veterinary science exclusively related with the treatment of horse. This is true also of the science of elephants of which the originator is said to be Pālakāpya.[66]. The dates of both Śālihotra and Pālakāpya cannot be established accurately. The texts dealing with horse and elephant are *Aśvaśāstra* of Nakula, *Aśvavaidyaka* or *Aśvāyurveda* of Jayadatta Sūri, *Hastyāyurveda* or *Gajaśāstra* of Pālakāpyamuni, *Mātaṅgalīlā* of Nīlakaṇṭha, and *Śālihotra* of Bhoja (c. 12th century A.D.). Incidentally these texts contain little information about the physiology of the horse and elephant. There is, however, one work on the entire animal and bird life. The text is *Mṛgapakṣiśāstra* of Hamsadeva (13th century A.D.) which discusses the life of beast and bird in a sort of poetical exaggeration with few factual observation.[66a]

In the disussion of biological idea, contributions of the Sanskrit texts are to be evaluated in respect of three concepts : Plants as living object, classification of animal according to the methods of reproduction, and concepts and development of human foetus.

I. *Plant as living object:*

The living objects are characterised by some common elements: These are soul and consciousness, nourishment and growth, and sexuality, reproduction and heredity. All these phenomena of living character were believed to be common in the plant which according to the Indian theory of evolution preceded animals, particularly man in the scale of creation.[67]

Soul and consciousness:

The idea of soul *i.e.*, the life principle in plant body is noticed first in the Vedic literature[68]. The plants are included here among the organic bodies.[69] They possess a living soul in the form of sap and are attributed with the power of hearing;[70] but they lack *citta* i.e., power of thinking[71].

The idea of consciousness in plant body is developed in the later texts beginning from the *Mahābhārata* to the philosophical texts found even in the 14th and the 15th centuries A.D. All these texts have recognized a sort of dormant, dull and stupified consciousness in plant body capable of experiencing the feelings of pleasure and pain. The first text distinctly discussing the consciousness of plant is the *Mahā-*

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[66] Winternitz, M. *History of Indian Literature*, Motilal Banarasi Dass, 1907, 3 (2) pp. 607, 608.

[66-a] Bose, M. D. M., Sen, S. N. and Subbarayappa, B. V. *Ibid*. Vide, 'Zoology' p. 439.

[67] *Taittirīya Upaniṣad*, ii. 1.3.

[68] *Aitareya Āraṇyaka*, i. 5. 1. 9.

[69] *Chāndogyopaniṣad*, vi. 11. 1.

[70] *Ṛgveda*, x. 97. 21; *Atharvaveda* xi. 6. 10.

[71] *Aitareya Āraṇyaka*, ii. 6, 1, 5,

bhārata. Acording to this text plants are endowed with five sense-organs[72]. The *Manu Samhitā*[73] (*c.* 2nd century A.D.) refers to the predominance of *tamoguṇa* (mass or inertia) in plant life. The plants, according to this text, possess "a sort of dormant or latent consciousness, and are capable of pleasure and pain" (*antahsamjñā bhavartyvete sukhaduhkhasamanvitāḥ*. Udayana in his *Kiraṇāvali* (10th century A.D.) recognizes the consciousness found in the plant body, is extremely dull (*atimandaḥ samjñitayā*)[74]. The same character of consciousness in plant body is admitted by the other authorities like *Bhāgavatapurāṇa*[75] (c. 10th century A.D. *tamahprāyā avyaktacaitanyāh*) and Cakrapāṇidatta (11th century A.D.) in his *Bhānumatī* (*Vṛkṣāstu cetanāvanto'pi tamasā cchannājñānatayā*).[76] Udayana (10th century A.D.) distinctly states the plants as manifesting the phenomena of living, death, dream, waking, susceptibility to disease and drugging, movements towards what is favourable and distraction from what is unfavourable[77]. Guṇaratna[78] (14th century A.D.) has enlisted a number of plants showing the phenomena of sleep and waking. The phenomena of sleep of certain plants at night is hinted by Dharmottara (*svāpah rātrau patrasamkocah*[79]). Guṇaratna refers to *lajjāvatī* (Mimosa pudica) as highly sensitive to touch.

Nourishment and Growth.—The nourishment of the plant body from the proper assimilation of watery solution by the agency of fire (i.e. solar rays) and air, is clearly stated in the *Mahābhārata*[80]. The *Atharvaveda*[81], however, though not so distinctly, refers to the idea of assimilation of rasa by means of *agni* (fire).

The *Mahābhārata* describes the processes of sucking the juice from earth and its assimilation. The idea of sucking by root is first mentioned in the *Chāndogyopaniṣad* where the plants are stated to feel exuberant joy by the extraction of juice from earth and its circulation to the whole plant body[82]. According to the *Mahābhārata* the plants drink water with the help of air through their roots in the same way as the water is sucked to the mouth through the lotus petiole: G.P. Majumdar has argued that the analogy, though imperfect, indicates that "the knowledge of the existence of a sucking force in the mouth of man—a knowledge which is only a very recent discovery—was an accomplished possession with the ancients"[83]. The water which is sucked is assimilated (*jarayati*[84]) by fire and air. A more acute knowledge about transportation of juice by the *syandanī* in the stem and *śirājālāni* in the leaves is found in the *Vṛkṣāyurveda* of Parāśara[85]. The text also mentions the assimilation of watery juice with the colour of leaves. These according to Sircar[86] suggest the food manufacture in the leaves.[87] The circulation of watery juice, according to Udayana, is done by *adṛṣṭa*. Śaṅkara Miśra (15th century A.D.) commenting on this *Sūtra* mentions that this transportation of juice to all the limbs of body is neither impulse nor impact, nor the sun's rays prevail there. It results from the conjunction of destiny with souls of these in whose souls pleasure and pain are effected by the growth of the leaves, stem, fruit, flowers, etc., as its non-coherent cause ; from destiny as its efficient cause and in water as its co-inherent cause. The *Bhāgavata Purāṇa* refers to the water transporting up in the trees, *utsrotasa*. A more clear idea is found in Guṇaratna's commentary on *Ṣaḍdarśanasamuccaya* where the assimilation of juice like that of the human body, and the diseased condition of plant on account of unsuitable food is stated in detail[89].

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[72] *Mahābhārata*—Published by Bhandarkar Oriental Research Institute, *Śāntiparva* 177,10-15.

[73] *Manu-Samhitā* i.49.

[74] *Kiraṇāvali* (Bibliotheca Indica Series) Calcutta, 1912. pp. 238-344.

[75] & 88. *Bhāgavatapurāṇa*.. (Ed. with Śrīdharaswāmin's commentery, Calcutta 1924 B.S. Ślokas 19-20.

[76] Seal, B. N.—Positive Sciences of the Ancient Hindus, Motilal Banarasi Dass, 1958, p. 175.

[77] See No. 74 (Cf. Guṇaratna's commentary on *Saḍdarsanasamuccaya, Bib. Indica*. 1907. Verse 49.

[78] *Saḍdarśanasamuccaya* Ed. by Luizi Suali with the commentary of Guṇaratna's *Tarkarahasyadīpikā*, Calcutta, *Bib. Indica* 1914) Verse 49, p. 157.

[79] *Nyāya-bindu-ṭikā*—Ed. by Peterson, (Bib. Indica) Cal. 1889. 2, 23.

[80] *Mahābhārata* (Śāntiparva), 177, 176.

[81] *Atharvaveda*, iv. 23. 6.

[82] *Chāndogyopaniṣad*, vi. 11. 1.

[83] Majumdar, G. P.—*Vanaspati*, University of Calcutta, 1927, p. 32,

The idea of growth of plant body by assimilated juice is distinctly stated in the *Mahābhārata*. This is also indicated by Guṇaratna. He even states the diseased condition of plant body, even its death due to unsuitable food.

The plant, like human body, passes throgh three stages of life, infancy, youth, and age. The stages are manifested in the different aspects of plant, like sprouting, seedling with new leaves, branching, and so forth[91].

The suffering of the plants from diseases, and their death due to unsuitable food have already been reported. The *Mahābhārata* refers to several plants suffering from fever caused by a kind of insect and by frost. The plants afflicted by this disease become pale and their leaves wither.

Sexuality, Reproduction and Heredity:

The idea of division of plants into male and female appears to be developed in India during the Vedic period. The *Atharvaveda* distinctly refers to several family-groupings of plants. In these groupings mention is made of some plants designated as mother, father, grandfather, brother and sister. This family-grouping of plants was neither arbitrary nor poetical exaggeration, but based on rational and scientific observation[92]. The mother and sister as stated in these groupings obviously show the female plants, while the others, like father, brother, etc., suggest male plants. The *Suśruta Saṃhitā*[93] refers to some plants like *Padma* (*Nelumbium speciosm*), *Utpala*

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84. & 90. *Mahābhārata, Ibid,* Verse 18.

85. & 86. Bose, Sen, & Subbarayappa, *Ibid.* vide,' Botany' p. 385.

87. *Vaiśeṣika Sūtras* of Kaṇāda. Sacred Book of Hindu Series (6) Panini office, Allahabad 1911 iv. 2. 5, pp. 159-160.

89-91. *Ṣaḍdarśana-samuccaya, ibid.* p. 157.

92. Roy, Mira—'Family-relation of Some Plantsin the Atharvaveda', *Indian Journal of History of Science,* 5 (1) 1970, pp. 162-172.

93. *Śarīra-Sthāna,* 3, 20.

Nymphaea caerulea), *Kumuda*, (white water lily) and *Amrātaka* (*Spondias magnifera*) as of masculine denomination. Caraka[94] has referred to two types of *vatsaka* (*Helarrhena antidysentrcia*), male and female. The male bears white flowers, large fruits and tender leaves ; and the female bears red and yellow flowers, and small fruits, small stalk. It is green-coloured. Amara mentions different nomenclature of pollen flowers. These are *rajas, puṣpa, prasūna*, which bear the same meaning, female menstrum. He further says that for females and flowers these elements are the same[95]. Hārīta, however, in an analogous way, states that the seed is produced by the co-operation of different sexes among the creeping and fixed plants, its quality varies according to the sperm. The fixed plants are endowed with *śiva* (static property) and *śakti* (dynamic property) principles. These two stand for male and female principles. The idea of male and female *ketakī* (*Pandanus odoratissimus*)[96] is an important observation of India. Majumdar suggests, "in one case we get the differentiation of sexes in plants based on actual observation."[97] The male is called *sitaketakī* and female one is designated *svarṇaketakī*. The former is also called *viphalā* (unproductive) and the latter *svarṇaprasavā*, i.e., producing golden harvest.

Propagation of plants by fruits and seeds, roots, cuttings, graftings, plant apices and leaves was known in India[98]. Elaborate processes are laid down in different texts for propagation of plants. Manu refers to propagation by seeds, *bījaruha*[98a]. The *Arthaśāstra* mentions propagation by bulbous roots, *kāṇḍabīja* and by cuttings, *skandhabīja*[99]. The *Bṛhatsamhitā* (c. 6 cent A.D.) describes the method of graftings, *kāṇḍaropya*, superior to cutting[99a]. Grafting was performed by inserting the cutting of one tree into the stem of another.

Like the other phenomena of plant life, heredity is not much discussed in the relevant texts. The question of transmission of character has been raised in some early texts of the Vedic literature, the *Brāhmaṇas*[100a]. Both Caraka and Suśruta[101] recognize that the fertilized ovum contains in minature all the organs of plant. The bamboo seed contains in miniature the entire structure of the bamboo, as the mango blossom contains the stone, pulp, the fibres which appear separated and distinct in the ripe fruit. The idea of transmisson of specific characters in plant life by means of ova (*sajātīyānuviddha*) is clearly stated in Udayana's *Kiraṇāvali*[101a].

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[94] *Caraka-Samhitā*—Tran. into Bengali by U. N. Sen & D. N. Sen, Calcutta, 1316, B.S. *Kalpa Sthāna*, 5, 3.

[95] *Amarakośa, Vanauṣadhivarga*, verse 50.

[96] *Rājanighaṇṭu* (*Karavīrādirdaśamavargaḥ*) verses, 1-3.

[97] Majumdar, B. P. *Ibid.* p. 61.

[98] *Vaiśeṣika-sūtra*: (Ed. and trans. into Eng. by B. Faddegon), 5, 27.

[98-a] *Manu Samhitā*, i.46.

[99] *Arthaśāstra, Ibid.* 2,.24.24.

[99-a] *Bṛhat Samhitā, Ibid*, 55, 5-6.

[100] Majumdar, G. P. *Ibid.* p. 141.

[101] *Caraka Samhitā, Ibid. Śarīra Sthāna*, 3, p. 449.
Suśruta Samhitā, Śarīra Sthāna, 3. 18.

[101-a] *Kiraṇāvali, Ibid.* pp. 238-244,

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II. *Classification of animals according to the mode of reproduction:—*

Classification of animals on the basis of reproduction is an important aspect of Indian biological thought. The early reference to this idea is found in the *Āraṇyakas* and in the *Upaniṣads* (c. 800 B.C.-600 B.C.). This, according to some,[102] is prior to Aristotle's (384-332 B.C.) *Scala Naturae* which though considered as the earliest scientific classification of animal kingdom, does not occur in any of his writings but "forciby extracted out of Aristotle's Text".

The idea of *bīja* (seed) for the propagation of life is first noticed in the *Atharvaveda*[103] (c. 1000 B.C.). This idea of *bīja* was developed in the later texts. The whole animal kingdom is classified in these texts into three or four divisions according to the mode of their propagation (*bīja*). The *Chāndogyopaniṣad* refers[104] to three biological orders : *aṇḍaja* (born of an ovum, egg), *jīvaja* (born alive, *i.e.*, born of uterus or rather placentalia, viviparous) and *udbhijja* (born of vegetable organism). A slight elaboration of this division is found in the *Aitareya Upaniṣad*,[105] along with the three, a new order, namely, *svedaja* (born of moisture and heat, spontaneously or as a-sexually generated) is found to occur in the list. The absence of this group in the *Chāndogyopaniṣad* can be explained by the view of Śaṅkara[106] (*c.* 8th century A.D.). According to him *svedaja* is partly included under *aṇḍaja*, and partly included under *udbhijja*. This four-fold dvision of the animal kingdom, as found in the *Upaniṣads*, is maintained in the *Caraka Saṃhitā*, *Suśruta Saṃhitā*, *Mahābhārata* and *Manu Saṃhitā*. There are variations, of course, in the arrangement of the orders, which is probably done on the basis of biologicl importance of a particular group conceived by a particular authority.

Apart from this four-fold division, two new types of classifications are noticed, one in the *Tattvārthādhigamasūtra* of Umāsvāti (40 A.D.) and the other in the *Praśastapādabhāṣya* (c.5th cent A.D.). In the *Tattvārthādhigamasūtra* classification is made according to the number of sense organs possessed by the living organisms. An interesting factor of this classification is the further sub-divisions of a particular order made on the basis of their reproduction. The *Praśastapādabhāṣya* has given two broad divisions: (i) *yonija* (sexually generated) which includes two orders, *jarāyuja* and *aṇḍaja* and (ii) *ayonija* (a-sexually generated).

In the Āraṇyaka-Upaniṣadic period mention of specific species associated with each order is not noticed. From about 500 B.C. onwards, however, the general practice of authors is to indicate the different species included in the four biological orders. New ideas about the species are incorporated in the texts and commentaries belonging to later period. According to some no clear-cut distribution of the species under a particular order can be made, as some of the species are found to belong to two separate orders. For example Ḍallanācārya[107] (12th century A.D.) has shown some species included both in the *svedaja* and in the *udbhijja* orders, and some included both in the *aṇḍaja* and the *jarāyuja* orders. He has cited the life-histories of (*i*) *balākās* included under *aṇḍaja* but having some species belonging to *jarāyuja*; (ii) the *ahipātaka* (snake) species originally belonging to *aṇḍaja* orders, are included in *jarāyuja group*; (iiii) *pipīlikā* or ants of the *svedaja* group, have some species which lays eggs (i.e., *aṇḍaja*), or 'bursts forth' (*i.e.*, *udbhijja*).

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[102] Keswani, N. H. "Concepts of generation, reproduction, evolution and human development as found in the writings of Indian (Hindu) scholars during the early period (up to 1200 A.D.) of Indian History", *Bulletin of the National Institute of Sciences of India*, No.21, 1963, p. 208.

[103] *Atharvaveda*, v.25,7-8.

[104] *Chāndogyopaniṣad*, vi.3.1.

[105] *Aitareya Upaniṣad*, iii, 1.3.

[106] *Chāndogya*, *Prapāṭhaka* 6, pt.3 (vide B. N. Seal, *Ibid*, p. 181).

The orders and species included in the four-fold divisions, as laid down in different texts excepting the Vedic literature where they do not occur, are given below.

Caraka Samhitā

Caraka[108] has described four methods of propagations for living beings. These are: *Jarāyuja* (viviparous), *Aṇḍaja* (oviparous), *Svedaja* (born of moisture and heat), and *udbhijja* (born of vegetable organism).

Caraka has not mentioned specific species associated with each division. According to him "among these four kinds of breeds, each single breed is of countless varieties by reason of diversities of the shapes of creatures being countless".

A slight modification of the orders given in the Upaniṣads by the addition of the idea " of countless varieties of each single breed" is found to occur in the *Caraka Samhitā*. No biological interpretation has been given here on the birth of "countless varieties".

Suśruta Samhitā[109]

The distribution of species under particular orders is first found in the *Suśruta Samhitā*. They are given below :

(*a*) *Samsvedaja* (born of moisture and heat)—This group is mentioned first, as Ḍallana[110] says, "moisture and heat are essential factors for the propagation of all living objects." This group includes *krimi*, *kīṭa* and *pipīlikā*.

Krimi (worm): Ḍallana[111] describes them as having their birth from the moisture of the faeces in the bowels. Different origins of *krimis* given by other authorities: Guṇaratna in his *Tarkarahasyadīpikā*[112] refers to *krimi* as "born from putrefying dead

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[107] Ḍallaṇācārya on *Suśruta Samhitā* i. 23.

[108] *Caraka Samhitā*. Ed. by Shri Gulabkunverba, Ayurvedic Society; with Introduction, commentary and indices including English, Hindi and Gujarati translation, Jamnagar 1949, Vol. 2. *Śarīra*, 3, 16.

[109] *Suśruta Samhitā, Sūtra Sthāna*, 1, 23.

[110 & 111] Ḍallanācārya on *Ibid*. (See Reference No. 107).

[112] *Saḍdarśanasamuccaya, Ibid*, p. 145.

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bodies"; Jayanta in his *Nyāyamañjarī* describes them as "born from decomposing of curd or milk[113]".

Kīṭa (insects): Suśruta[114] and Patañjali[115] (150 B.C.) refer to them as originating from cowdung, exereta of snakes and rotton wood. Ḍallana includes scorpion and six-spotted venomous insects in this group.[116].

(*b*) *Jarāyuja* (viviparous)—This group includes *manuṣya* (man), *vyāla* (carnivorous quadrupeds), and *paśu* (herbivorous quadrupeds).

(*c*) *Aṇḍaja* (oviparous)—This group includes: *khaga* (birds), *sarpa* (snakes), *sarīsṛpa* (reptiles).

(*d*) *Udbhijja* (vegetable organisam)—This group includes: *indragopaka* (cochineal), *maṇḍūka* (frogs).

Tattvārthādhigamasūtra:

The group of animals possessing five senses is sub-divided into six classes. Omitting 'man', this group comprises : (*i*) *matsya* -fishes, (*ii*) *uraga*—limbless reptiles including snakes, (*iii*) *bhujaṅga*—limbed reptiles and amphibians, (*iv*) *pakṣi*—bird (Aves), and (*v*) *Catuṣpada*—quadrupeds (Mammalia)[117].

This group is sub-divided into three on the basis of reproduction: *jarāyuja aṇḍaja* and *potaja*.

(*a*) *Jarāyuja* (viviparous, placental mammals)—Here *Jarāyuja* is restricted to mean those mammals which have non-deciduate placenta.[118] This group includes: *manuṣya* (man), *go* (cow), *mahiṣa* (buffalo), *aja* (sheep), *khara* (ass), *uṣṭra* (camel), *mṛga* (deer), *camara* (yak), *gavaya*, *varāha* (hog), *simha* (lion), *vyāghra* (tiger), *ṛkṣa* (bear), *dvīpi* (panther), *śvā* (dog), *śṛgāla* (jackal), *mārjāra* (cat), etc.

(*b*) *Aṇḍaja* (oviparous)—This group includes: fishes and reptiles, including *sarpa* (snakes, *ophidia reptilla*), *godhā* (chameleons, reptilla), *kṛkalāsa* (common lizards, *Lacentilia*), *matsya* (fish), *kūrma* (tortoise), *nakra* (crocodiles), *śiśumāra* (*Dolphin*) and birds proper with feather wings (*lomapakṣa pakṣis*).

(*c*) *Potaja* (viviparous), probably indicates "to throw off no placenta"[119]. This group includes: *sallaka* (porcupine), *hasti* (elephant), *śvāvit* and *lāpaka* (hedgehog and other insectivores), *śaśa* and *śāyika* (hares and squirrels), *nakula* (mongoose), *mūṣika* (rat and mice), and the *carmapakṣa-pakṣi* (birds with leathern wings *i.e.*, bats)

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[113] *Nyāyamañjarī* of Jayantabhaṭṭa—*Āhnika* 4. *Bhūtacaitanyapakṣa* (vide Seal. *Ibid.* p.180)

[114] *Suśruta Samhitā*, *Ibid.* also *Kalpasthāna*, 8, 2.

[115] *Mahābhāṣya* Ed. by F. Kielhorn, Bombay, 1880. Vol. 1. i. 4, 3. p. 329.

[116] Ḍallanācārya, *ibid.* (See Reference No. 114).

[117] *Tattvārthādhigamsūtra* of Umāsvāti. Ed. by Kesavlal, with Umāsvāti's own commentary, ii. 24, 34.

[118] Bose, Sen & Subbarayappa, *Ibid.* vide. 'Zoology' p. 429.

[119] Seal, B. N.—*Ibid.* p. 200.

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which includes *valguli* (flying fox), *pakṣi virāla* (flying cat, *Micro-chiroptera*) and *jalūkā* (blood-sucking bats or vampires).

Mahābhārata[120]:

(*a*) *Aṇḍaja* (oviparous)—This group includes all birds and *sarīsṛpas* (reptiles)

(*b*) *Samsvedaja* (moisture-born)—*krimis* (worms), are included under this.

(*c*) *Udbhijja* (vegetable organism)—The group comprises "those born after the lapse of time bursting through the earth". (*viz.* trees and plants).

(Difference is noticed here between the view of Suśruta who includes *indragopa*, etc., under *udbhijja* and the *Mahābhārata* which suggests the group indicating trees and plants under *udbhijja*).

(*d*) *Jarāyuja* (viviparous)—This group includes : (*dvipada* (beings of two feet), *bahupada* (beings of more than two feet.) and *tiryaggati* (those which move crookedly).

Manu Samhitā[121]:—

(*a*) *Jarāyuja* (viviparous)—This group includes: *paśu* (herbivorous quadrupeds), *vyāla* (carnivorous quadrupeds), *ubhayatodata* (beasts with two rows of teeth), *rākṣasa*, *piśāca* and man.

(*b*) *Aṇḍaja* (oviparous)—This group includes: *pakṣi* (birds), *sarpa* (snakes), *nakra* (crocodile); *matsya* (fixh), *kacchapa* (tortoises), etc.

(*c*) *Svedaja* (moisture-born)—This group includes: *damśa* (stinging insects), *maśaka* (biting insects), *yūka* (lice), *makṣikā* (flies), *matkuna* (bugs).

(*d*) *Udbhijja* (vegetable organism)—It includes all plants propagated by *bīja* (seed), *kāṇḍa* (slips), *prarohiṇa* (grown from shoot), and *oṣadhis* (annual plants).

Praśastapādabhāṣya[122]:—

Praśastapāda in his commentary on *Vaiśeṣika Sūtra* refers to two broad divisions of animal kingdom: (*i*) *yonija* (sexually generated from the union of a sperm and germ element) which is further divided into two classes, *jarāyuja* and *aṇḍaja*, and (ii) *ayonija* (a-sexually generated) which is called the *kṣudrajantus*.

Ayonija (a-sexually born):—

They are stated as born from the aggregates of *aṇus* and are called *ksudrajantus*. Patañjali in his *Mahābhāṣya*[123] gives a number of definitions of the *kṣudrajantus*. They are defined as (*i*) animals without bones (*anasthika*); or (*ii*) animals that do not possess any blood of their own (*yeṣām svaṃ śoṇitam nāsti*); or (*iii*) numbering

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[120] *Mahābhārata*, *Ibid*. *Aśvamedhikaparva*, xiv.42.19-23.

[121] *Manu Samhitā*, i. 43-46.

[122] *Praśastapādabhāṣya* Ed. by Subhadra Jha, with the *Nyāyakandali* of Śrīdhara, Varanasi 1963. *Prithivinirūpaṇa*, p. 82.

[123] *Mahābhāṣya*, *Ibid*. ii.4.1.p.474.

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more than a thousand in a palmful; or (iv) not easily crushed, or (v) comprehending all animals up to the ichneumon.

III. *Conception and development of human foetus:—*

The formation of embryo and its gradual development in a mother's womb, is an important theme of Indian biological ideas which can even fit into the concept of the modern times. The ideas relating to the formation of semen and blood, and the gradual development of human foetus are discussed metaphorically or directly in different Sanskrit texts from the *Vedas* to the *Āyurveda*.

The Upaniṣads[124] though they eulogize semen (*retaḥ*) as the essence of food, are not concerned about the physiological aspects of the formation of semen and blood, the two potent factors resulting in conception. However, the *Garbhopaniṣad*[125], a work of unknown date, gives a detailed account of the formation of semen, but the text is completely silent about the formation of the *ārtava* viz., menstrual blood, or simply blood. According to this text semen is formed from the six *rasas* (chyle). From blood comes flesh, from flesh fat, from fat tendons, from tendons bones, from bones marrow, and from marrow is produced semen. The *Suśrutā Samhitā* also holds the same view regarding the formation of semen. In addition to this it describes the formation of menstrual blood (*ārtava*) from the rasa (*chyle*) which owes its redness to the healthy bile. The semen and blood inhere in them the properties of the bhūtas, *i.e.*, five elements. Semen is attributed with the qualities of *Soma*, *i.e.*, thermolytic properties and blood is endowed with the qualities of *agni*, i.e., thermogenetic properties.

Both of them contribute their respective traits to the formation of embryo.[126]

The clear statement about the theory of conception from the conjunction of semen and blood, first occurs in the *Atharvaveda*[127]. The Āyurvedic treatises add another factor for the formation of embryo. This is the association of '*Ātman*' *i.e.*, "self" with the combined ovum and sperm in the uterus. According to the *Suśruta Samhitā*[128] conception does not arise from the mere union of semen and blood until these combined principles come in contact with *Ātman*, who is endowed with a subtle body and attributed by the qualities of five subtle or essential material principles contributed by the united impregnating matters, and by the three fundamental qualities of *sattva, rajas* and *tamas*, When the different elements of matter in conjunction with the subtle body associate with 'self', they have the appearance of a little lump of mucus, the first stage of the embryonic development[129].

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[124] *Taittirīya Upaniṣad*, ii. 1. 3; *Bṛhadāraṇyakopaniṣad*, vi. 4. 1. *Chāndogyopaniṣad*, v. 6. 2; 7. *Maitrāyaṇa Brāhmaṇopaniṣad*, vi. 10.

[125] *Garbhopaniṣad*, vide. *Upaniṣadām samuccayah* Ed. by Hari Narayana Apte, Anandasrama Series, verse 2.

[126] *Suśruta Samhitā*, *Śārīrasthāna*, 3, 2.

[127] *Atharvaveda*, vi. 11, 2.

[128] *Suśruta Samhitā*, *Ibid*. 3, 2.

[129] *Caraka Samhitā*, *Ibid*, *Śārīrasthāna*, 4, 8.

The development of human embroyo from its jelly-like appearance to a full-grown child has been so well described in different texts that one is amazed at the acuity of their observations. According to some this elaborate and minute observation about the growth of the human foetus cannot be made without studying the embryo-genesis in experimenal animals.[130] In the various texts of the Vedic literature some scattered information is obtained relating to the movement of foetus in mother's womb[131], its nourishment from the mother's body[132], its natural form taking place in the fifth month,[133] etc. The early text which gives a detailed description of the development stages of human embryo is *Garbhopariṣad*[134]:

"One night after the union following menstrual period, the foetus is of the form of a round lump (*kalala*), After seven nights it is of the form of a bubble-like vesicle (*budbuda*). After half a month a spherical mass, *piṇḍa*, is formed. After a month it becomes a solid mass (*kaṭhina*). After two months the head is formed and after three months, limb buds appear. During the fourth month the digits (*aṅguli*), the gut (*jaṭhara*) and the pelvic region (*kaṭī-pradeśa*) are formed. During the fifth month the vertebral column (*Pṛṣṭhavamśa*) is formed. During the sixth month mouth, nose, eyes, ears, etc., develop. During the seventh month the foetus becomes endowed with life (*jīvena saṃyuktā bhavati*). By the eighth month it becomes fully developed."

In the two medical texts, namely, the *Caraka Samhitā* and the *Suśruta Samhitā* there is a more detailed description of the foetal development, not only of its anatomical growth but also the gradual development of the sense-organs. The texts also describe the specific shapes of the condensed mass for the birth of male, female and eunuch. The description of the foetal development occurs in the *Caraka-Samhitā*[135]: "The spirit having become the embryo in the first month after conception being well compounded and tinged with all the elements, appears as a jelly-like mass (*kheṭa*). In the second month this mass hardens into the form either of a knot (*piṇḍa*) or a tendon (*peśī*) or an egg (*arbuda*). Of these the knot-shaped is male, the tendon-shaped female, the egg-shaped eunuch. In the third month all the sense-organs and the limbs of the foetus manifest themselves simultaneously. In the fourth month the foetus becomes stabilised. In the fifth month there is a greater increase to the foetus, in the accession of flesh and blood than during the other months. In the sixth month there is a greater increase in the accession of strength and pigmentation (*balavarṇopacaya*) than during the other months. In the seventh month, the foetus develops in all ways. In the eighth month, on account of yet incomplete formation of the foetus there is a continuous transmission of vitality (*ojaḥ*) from the mother to the foetus and *vice versa* by means of channels that carry the body-nutrient fluid". The observation of Suśruta regarding the foetal development is slightly different from that of Caraka. The description[136] contains: "In the first month of gestation a gelatinous substance is only formed ; the molecules of the primary elements being acted upon by cold (*kapha*), heat (*pitta*), and air (*vāyu* or nerve-force) are condensed in the second month. A lump-like (*piṇḍa*) appearance (of that confused matter) indicates the male sex. An elongated shape (*peśī*) of the matter denotes that the foetus belongs to the opposite sex; whereas its tumour-like (*arbuda*) shape predicts the abesence of any sex (*i.e.*, hermaphrodite). In the third month, five lump-like protuberances (*pañcapiṇḍaka*) appear at the places where the five organs—namely the two hands, the two legs and the head—would be, and the minor limbs and the members of the body are formed in the shape of extremely small papillae. In the fourth month all the limbs and organs (of the body of the embryo) become more potent and the foetus is endowed with consciousness owing to the viscus of the heart and hence it expresses its desire for things of taste, smell, etc. In the fifth month the foetus is endowed with mind and wakes up from the sleep of its sub-conscious existence. In the sixth month cognition (*buddhi*) comes in. In the seventh month all the limbs and members of its body are more markedly developed. The *ojodhātu* (in the heat of the foetus) does not remain silent in the eighth month. A child born at that time dies for want of *ojo-dhātu* soon after its birth. The parturition takes place either in the ninth, tenth, eleventh, or twelfth month of conception, otherwise something wrong with the foetus should be appreciated." Equally important is Suśruta's[137] observation on the transmission of essence of lymph-chyle from the mother's body to the foetus by means of the vessels of maternal part attached to the umbilical cord (*nāḍī*) of the foetus. It is not only the foetal development; these texts are also particular about discussing the definite contributions of the parental elements to the specific organic development in the foetus body.[138]

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[130] Keswani, N.H. *Ibid*, p. 212.

[131] *Ṛgveda*, x. 169. 3.

[132] *Pañcavimśa Brāhmaṇa*, ii. 2. 1. 10.

[133] *Śatapatha Brāhmaṇa*, ix. 5. 1. 63.

[134] *Garbha Upaniṣad*, verse 3.

[135] *Caraka-Samhitā* (Jamnagar Edition), *Śarīrasthāna* 4, 9-11, 20-24.

The sources, just discussed above, are not the sole area of study on the ancient Indian thoughts and ideas about the conception and the embryonic development. The contributions of other Sanskrit texts like the *Mahābhārata*[139] and the *Yājña-valkya Smṛti*[140] are to be evaluated in respect of their observations on the conception and development of human foetus.

A perusal of the above discussion shows the following trends of chemical and bio-scientific contents of the Sanskit texts :

(*a*) Uniformity of scientific concepts and practices found in contemporary or near contemporary literary sources.

(*b*) Additions of considerable amount of new and improved knowledge on some initial fundamental ideas through the later Sanskrit texts which led to the development of new types of scientific literature.*

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[136] *Suśruta Samhitā*, *Śarīrasthāna* 3, 14-16.

[137] *Ibid*, 3, 17.

[138] *Ibid*, 3, 19.

[139] *Mahābhārata*, *Ibid*. *Śāntiparva* 308, 116-117.

[140] Choudhury, Mamata "Embryonic Development and Human Body in the *Yajñavakya Smṛti*", *Indian Journal of History of Science*, 2, (1967), pp. 52-60.

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LUNAR AND SOLAR EQUATIONS OF HINDU ASTRONOMY

N.C. Lahiri, M.A., *Ganitacharya, Ganitakalanidhi*

After the Vedāṅga Jyotiṣa period, which persisted in India from the 13th century B.C. to the 4th century A.D., giving very crude positions of the Sun and the Moon, there was sudden rise of scientific astronomy in this country, when treatises on Siddhānta Jyotiṣa starting from *Āryabhaṭīyam* of Āryabhaṭa I (499 A.D.) began to make their appearance. The eminent astronomers of this renaissance period starting from Āryabhaṭa were Varahāmihira (C. 550 A.D.), Brahmagupta (628 A.D.), Lalla (748 A.D.), Muñjāla (932 A.D.), Śrīpati (1039 A.D.) and Bhāskara II, 1150 A.D.), who made great contributions to the science of astronomy in India. But as in the case of other branches of science like Medicine and Mathematics, the Indian savants did not keep any trace of the observational methods employed by them in arriving at different astronomical constants adopted in the treatises compiled by them. This lacuna on their part has led to the conjecture made by some research workers that the Indian astronomers had postulated their theories on astronomical constants borrowed from the west, *viz.*, from the Babylonians and Chaldeans, in spite of the fact that the astronomical constants of the latter group substantially differ from those of the Indians. The critical examination of this point is however not the scope of this paper. However, an attempt will be made here to examine critically the values of some of the constants of inequalities of the Moon and the Sun adopted by the Hindu astronomers in comparison to the correct values of the constant as determined from modern observations.

Most of the astronomical constants employed by the makers of Hindu Siddhāntas show wide divergences from the corresponding values of modern determination. This gives the natural conclusion that the Indian astronomers were not very good observers of the motions of the heavenly bodies. It will however be presently shown that their determinations were not so bad as is generally thought of by some of the new entrants into the subject.

Let us first take the equations of centre of the Moon and the Sun by which the mean positions of the luminaries are corrected to get their true positions. From our Siddhāntas we get that the equation of centre of the Moon has been adopted as $300'.9 \sin A$ and of Sun as $130'.7 \sin g$, where A and g are the mean anomalies of the Moon and the Sun respectively. These values are quite different from those found in modern astronomy. Let us first examine the case of the moon.

For finding the true longitude of the Moon from its mean longitude, corrections given by a good number of terms are required to be applied. We cannot get the result by application of only one term *viz.*, the equation of the centre as contemplated by Hindu Astronomers. The principal terms of moon's inequality according to modern astronomy are as follows:

$+ 377'.3 \sin A$ .. Equation of centre
$+ 76'.4 \sin (2T\text{-}A)$ .. Evection
$+ 39'.5 \sin 2T$ .. Variation
$- 11'.2 \sin g$ .. Annual equation

where A=mean anomaly of the moon *viz.* mean moon—lunar perigee

g=mean anomaly of the Sun *viz.* mean sun—solar perigee.

T=mean moon—mean sun *i.e.*, mean Tithi for the moment.

Let us now examine what form the above equations take at syzygies. At new moon and full moon T becomes 0° and 180° respectively giving the value of $2T=0$ at both the epochs. Putting $2T=0$ in the above equations, we get the value of the inequalities at syzygies reduced to the following two terms only—

$$+ 300'.9 \sin A \qquad - 11'.2 \sin g$$

The above reduced terms of 300'.9 now arrived at from modern astronomy agrees exactly with that as adopted in Indian astronomy mentioned earlier although the equation is valid only at new moon and full moon.

As regards the equation of centre of the Sun, the modern value of its principal term is $115'.2 \sin g$; in 500 A.D. its value was $119'.1 \sin g$, slightly greater than the present value. The corresponding term of the Indian astronomers is much more, *viz.*, they use a value of $130'.7 \sin g$, which does not compare favourably with the correct value of $119'.1 \sin g$. But when we consider that the Indian astronomers were more interested in correctly determining the times of new moon and full moon and consequently the times of solar and lunar eclipses, it is possible to find out an explanation for the above discrepancy in the solar equation also. Taking the terms from modern astronomy depending on g alone in the solar and lunar equations, we get

$$\text{Solar term—lunar term} = 119'.1 \sin g - (-11'.6 \sin g)$$
$$= 130'.7 \sin g.$$

(119'.1 and 11'.6 are the values of the terms of 500 A.D.). It will thus seen from the above that the Hindu astronomers showed the highest ability in determining the value of the sun's equation of centre combined with the lunar part as applicable at new moon and full moon. It may however be stated here for the facility of comparison that the value of this term *i.e.*, sun's equation of centre adopted by Ptolemy was as high as 143' widely differing from the above values. Let us now examine how the remaining terms of the lunar equation were dealt with by the Hindu astronomers. After taking away the term of the moon's equation of centre of the Hindu astronomy *viz.* $+300'.9 \sin A$ from the complete expression of modern astronomy, we get the remainder as

$$\begin{aligned} &+\ 76'.4\ \sin A \\ &+\ 76'.4\ \sin (2T-A) \\ &+\ 39'.5\ \sin 2T \end{aligned}$$

The true position of the moon is affected by the above terms during the whole month except at new moon and full moon when the sum total of the above terms become zero. The discrepancy in the moon's position caused by the above neglected terms amounts to about 3 degrees in the moon's position at times resulting in an error of 6 hours in the timings of tithi, etc. This divergence came to the notice of Indian observers as early as in the 10th century A.D. and Muñjala, Śrīpati and Bhāskarācārya tried to formulate correct expressions to make good these deficiencies with the values of co-efficients as they could determine by observation.

The residuary terms given above can be reduced to the following expression after combining the first two terms into a single one by trigonometric transformation, namely

$$+152'.8 \cos (T-A) \sin T + 39'5 \sin 2T$$

The first of the above two terms is given by our astronomers Muñjala in his *Laghumānasa* (932 A.D.), and Śrīpati in his *Siddhāntaśekhara* (1039 A.D.), but the co-efficients given by them were a bit different from the above value of 152′.8. Muñjala gives 144′ as the value of this co-efficient while Śrīpati erring on the other side by almost an equal amount of 8′ gives 160′. These co-efficient however undergo slight fluctuations during the month according to the daily motion of the moon. The part of the trigonometrical expression given by both the Indian astronomers is in the form

$$-\cos (\text{Sun-lunar apogee}) \sin T$$

which is $-\cos (\text{Sun-Moon} + \text{Moon-apogee}) \sin T$

$$\begin{aligned} &-\cos (T + A - 180°) \sin T \\ &-\cos (T-A + 180°) \sin T \\ &\cos (T-A) \sin T \end{aligned}$$

which is exactly the same as given by the modern equation.

The above error in the co-efficient amounting to ± 8′ is produced by an error of ± 4′ in the co-efficient of the terms of the equation of the centre and Evection. This is apparently due to an error or uncertainty in the determination of the longitude of the Moon by observation. The reason for this error may however be ascribed to the fact that the Hindu astronomers used a value of the horizontal parallax of the moon less by 4′ than the correct value, their value of mean parallax being 53′ against the modern value of 57′. The observed position of the Moon is shifted by the amount of the lunar parallax from its calculated geocentric position which might give the above error of 4′.

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Bhāskarācārya (1150 A.D) in his later book '*Bījopanaya*' written after the famous work *Siddhāntaśiromaṇi* has dealt with the above residuary terms of the moon's equation. Unlike his predecessors he has retained the three terms separately without making any sort of combination of terms. His co-efficient of the terms are rather improved as he has taken 78 as the co-efficient for both the first and second terms as against the correct value of 76′.4, the error being less than 2′ in this case. The greatest credit that goes to Bhāskarācārya in this respect is the introduction of the third term *viz.*, the variation term with 34′ as its co-efficient. His Term $+34' \sin 2T$ in the moon's equation, which was not found by his predecessors Muñjala and Śrīpati as not so bad is compared with the correct value of $39' \sin 2T$. The variation term was introduced by Bhāskara, about 400 years before the same was done in the West by Tycho Brahe in 1590.

It is really deplorable that India having such a glorious past in the field of astronomy is now lagging behind in the work of astronomical computations. The makers of the so-called old school Pañcāṅgas of our country are still following the ancient Siddhāntic rule of determining the Moon's position for their Pañcāṅgs applying only one term *viz.*, the reduced value of the equation of the centre ($301' \sin A$) whereas the above-mentioned illustrious Indian savants of later age had already discovered in our country the other inequalities of moon's motion for introduction in the Pañcāṅga calculation. It is however good for our country that at the initiative of the Government of India, the Indian Meteorological Dept. has undertaken publication of Pañcāṅgas giving correct positions of the moon and the sun and the correct timing of Tithis etc., as derived therefrom. This has infused in many Pañcāṅga-makers of our country the spirit of adopting correct elements for their Pañcāṅgas and it is hoped that before long the remaining old school Pañcāṅgas would also follow the same path and thereby help regain for India a high position in the field of astronomy as she had enjoyed during the last 1500 years.

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SANSKRIT AND MATHEMATICS

Dr. T A. Sarasvati

Mathematics occupied an honoured place in India from very early times. Jyotiṣa or astronomy was the most important of the Vedāṅgas of the Vedic religion[1], and Gaṇita or mathematics was one of the four Anuyogas (ancillary studies)—धर्मकथानुयोग, गणितानुयोग, etc. necessary for the study of the religious literature of the Jainas. Amongst the educational qualifications of Gautama Buddha, knowledge of Gaṇita is given pride of place.

The name Gaṇita (etymologically computation) is used to denote mathematics in general; geometry is Kṣetragaṇita, but usually it forms part of arithmetic which is termed Pāṭigaṇita, and algebra is Bījagaṇita or Avyaktagaṇita. No special name is used for trigonometry since it always formed part and parcel of astronomy. Series-mathematics is called Śreḍhīgaṇita. All these branches of mathematics were often seen as appurtenances to the study of astronomy and so chapters on mathematics are included in many of the astronomical texts. The early Siddhāntas, the *Pañcasiddhāntika* of Varāhamihira (*c.*6th century)[2] and the *Sūryasiddhānta* of unknown date, do not contain such chapters. From Āryabhaṭa I (b.476 A D.) downwards they become a regular feature of most Siddhānta texts. The *Āryabhaṭīya*, the *Brahmasphuṭasiddhānta* of Brahmagupta (628 A.D.), the *Mahāsiddhānta* of Āryabhaṭa II (c. 950 A.D.), the *Siddhāntaśekhara* of Śrīpati (c.1039 A.D.) devote separate sections to mathematics. Though Bhāskara II (12th cent.) has separate treatises on arithmetic (*Līlāvatī*) and algebra (*Bījagaṇita*) they are really meant to be sections of his *Siddhāntaśiromani*. There is hardly any separate work on geometry except the *Sulbasūtras*. The known *Pāṭīgaṇita* texts are the Bakshali manuscript (date uncertain, but decidedly early), the *Gaṇitasārasaṁgraha* of Mahāvīra (c 850), the *Pāṭīgaṇita* (of which a part only is available) and the *Triśatikā* of Śrīdhara, who may be placed before Mahāvīra though Dr. K.S. Shukla places him after the *Gaṇita-tilaka* of Śrīpati (c. 1039 A.D.), the *Līlāvati* of Bhāskara II (c. 1150 A D.). the *Gaṇitakaumudī* of Nārāyaṇa (1356 A.D.), and the *Pāṭīsāra* of Munīśvara (b. 1603 A.D.). The *Āryabhaṭīya Bhāṣya* of Nīlakaṇṭha (born c. 1465), the first part of the *Yuktibhāṣā* of Jyeṣṭhadeva (16th cent.) and the *Kriyākramakārī* (of unknown authorship but probably of the same century) also deserve to be treated as separate treatises on mathematics while the *Tantrasaṁgraha* of Nīlakaṇṭha, the *Karaṇapaddhati* of Putumana Somayājin

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1. "यथा शिखा मयूराणां नागानां मणयो यथा ।
तद्वद् वेदाङ्गसूत्राणां गणितं मूर्धनि स्थिम् "

—Vedānga Jyotiṣa quoted in *Hindu Mathematics*, Part I, p. 7f.

2. The Siddhāntas summarised in the *Pancasiddhanltka* are much older.

(early 18th cent.) and the *Sadratnamālā* of Śaṅkara Varman (late 18th century) also contain mathematical material.

The original users of Samskṛit, the Vedic Āryans, were a poetically gifted race who visualised and worshipped godhead in the glory and beauty and terror of nature around them. This phase of spontaneous poetic adoration gave place gradually to a sacerdotal religion of sacrifices while speculation and reflection made inroads on imaginative power. This change, regrettable in many ways, was beneficial in one field, that of the sciences. A critical study of language led to the perfection of a wonderful system of grammar and philology. The meticulous attention bestowed on sacrifices laid the foundation for mathematics and astronomy amongst the physical sciences and physiology and medicine amongst the biological sciences.

The cult of the sacrifice prescribed exact areas and geometrical shapes to the sacrificial altars and fire-places. Out of the necessity of constructing these grew up an amount of geometrical knowledge which is codified in the *Śulbasūtras* which form a part of the *Kalpasūtras*, one of the six Vedāṅgas. The most significant contribution of the *Śulbasūtras* to mathematics is the enunciation in general terms of the theorem of the square on the diagonal, an achievement to be dated around the 8th century B.C., the probable date of the *Baudhayāna Śulba sūtras*. It is possible that Pythagoras got the knowledge of this theorem, now coupled with his name, from India during his travels abroad.

A number of accurate geometrical constructions for the perpendicular bisector, rectangle, square, trapezium, isosceles triangle and rhombus, reduction of rectangles, trapezia, triangles etc., into equivalent squares and *vice versa;* construction of a square equal in area to any multiple of the area of a given square, a square equal in area to the sum of two or more given squares etc., —these form the bulk of the contents and imply a considerable amount of geometrical knowledge. The widest use is of the theorem of the square on the diagonal and its converse. Many sets of sides of right triangles, mostly integral but some fractional and some with one side given as the approximate value of a surd are found used in the *Śulba sūtras*. Also one rule given in the *Āpastamba Śulbasūtras* (I,3) seems to imply the knowledge of a general solution of the rational right triangle, viz. $2n(n+1)$, $2n+1$, $2n(n+1)+1$, Kātyāyana's rule for combining any number of squares into an equivalent square (*Kātyāyana Śulba sūtra* VI, 7) leads to another general solution $m, \frac{m^2-1}{2}, \frac{m^2+1}{2}$. Through the use of the theorem of the square on the diagonal the *Śulbasūtra* authors evaluate geometrically square roots and surds. For $\sqrt{2}$ a remarkably close approximation

$$\sqrt{2} = 1 + \frac{1}{3} + \frac{1}{3.4} - \frac{1}{3.4.34}$$

is found recorded. By a study of the areas of squares with different sides, they succeeded in having a clear grasp of the meaning of the multiplication of fractions. They were familiar with some of the properties of similar figures too. They must also have known how to calculate accurately the volume of a parallelopiped.

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The mensurational bent given to geometry by the altar-building Vedic priests was strengthened by the early Jainas who measured the circumferences, chords and areas of the continents and oceans (which according to their cosmography stretched forth in concentric circles on a flat, circular earth), as also the circular paths of the heavenly bodies to minute fractional units. Before the beginning of the Christian era, the Jaina canonical literature records expressions for the circumference and area of circles with $\pi = \sqrt{10}$, the expression $c = \sqrt{4h(d-h)}$ for the chord and rough approximations for the arc and the segment. The *Sulbasūtras* too contain a much grosser calculation of the area of a cricle. Āryabhaṭa I (b.476 A D.) has a good approximation for π, viz.,

$$\pi = \frac{62832}{20000} = 3.1416,$$

though the use of this value was perhaps confined to the preparation of the sine tables and in other fields the old value of $\sqrt{10}$ continued in use for some time more. Later, in the Āryabhaṭa school, much closer approximations, in fact approximations to any desired degree of closeness were achieved. So also the very rough value for the arc, $\sqrt{c^2 + 6h^2}$, is improved as $\sqrt{c^2 + h^2\left(1 + \frac{1}{3}\right)}$ by Nilakaṇṭha of the Āryabhaṭa school at the end of the 11th century and with the help of infinite series developed in the school, it could be calculated to any degree of closeness.

The isosceles trapezium is a shape which very early attracted attention, both from the Vedic and Jaina religions. Before the dawn of the Christian era, the sacerdotal cult faded in importance and astronomical and astrological studies gained in importance with a resultant emphasis on the study of the circle (the celestial circle), whence the cyclic quadrilateral came to be studied from different aspects. Brahmagupta has the credit of discovering the expressions:

Area of a cyclic quadrilateral $= \sqrt{(S-a)(S-b)(S-c)(S-d)}$

The diagonals of a cyclic quadrilateral $= \sqrt{\dfrac{(ab+cd)(ac+bd)}{ad+bc}}$

and $\sqrt{\dfrac{(ad+bc)(ac+bd)}{ab-cd}}$

The latter was rediscovered in Europe by W. Shell in 1619 A.D. The proof for these is given in the 18th century work *Yuktibhāṣā* belonging to the Āryabhaṭa school. The expression $A = \sqrt{S(S-a)(S-b)(S-c)}$ for the area of a triangle is derived from this by considering the triangle as a quadrilateral with one side $= 0$, and later proved independently. The general quadrilateral received little attention. Āryabhaṭa II and Bhāskara II were the only mathematicians to deal with it. In fact, by Brahmagupta's time most rectilinear figures were probably viewed as figures bounded by chords. Such was the ascendancy of the circle. The expression for the radius of the circumcircle of a quadrilateral,

$$R = \sqrt{\frac{(ab+cd)\,(ac+bd)(ad+bc)}{(a+b+c-d)\,(b+c+d-a)\,(c+d+a-b)\,(d+a+b-c)}}$$

was known in the Āryabhaṭa school at least by the 15th century. This can easily be reduced to the form

$$R = \frac{1}{4}\sqrt{\frac{(ab+cd)(ac+bd)(ad+bc)}{(S-a)(S-b)(S-c)(S-d)}}$$

which Lhuiler rediscovered in 1782. Nārāyaṇa in the 14th century discovered two theorems connected with the cyclic quadrilateral, viz., "Three and only three diagonals are possible for the four side-lengths of a cyclic quadrilateral" and "The area of a cyclic quadrilateral is the product of these three diagonals divided by twice the circum-diameter",

The name for the triangle is tryaśri, tribhuja, tribāhuka etc., all meaning "possessed of three sides". Apparently, the concept of angle had not entered into the nomenclature or treatment. But we have to remember that in Indian mathematics "bhuja" primarily means a chord and arcs took the place of angles. The name Prauga for the isosceles triangle occurring in the *Sulbasūtras* does not have any mathematical significance. The area of this triangle was known to be ½ base x altitude. The right-angled triangle with many rational solutions and one or two general rational solutions is quite well known. From Brahmagupta onwards the construction of other rational figures, the triangle, the trapezium and the cyclic quadrilateral, by the juxtaposition of rational right triangles. is a regular feature of most mathematical works. The expressions for the perpendiculars (lamba) and the projections (ābādhā) of the sides on the base etc. also occur commonly.

Interest in solid geometry was limited to mensurational formulae. In addition to the ability to calculate correctly the number of bricks required for the sacrificial altars and fire-places, the *Sulbasūtra* authors knew that a parallelopiped is cut into two prisms of equal volume by the plane passing through the parallel diagonals of one pair of opposite faces. Āryabhaṭa I though aware of the expression for the number of shots in a pyramidal pile, seems to give wrong expressions for the volumes of the tetrahedron and the sphere*. The Jaina canonical works must have been familiar with the formulae for the volumes of the trapezoidal solid, the cylinder and the prism with right triangular section. From Brahmagupta onwards, the correct volume of the pyramid and cone are known. Vīrasena in the 8th century derives the expression for the volume of the frustum of a cone by cutting it up into a cylinder and wedges. Though the correct formula for the volume of a sphere seems to have been known to Śrīdhara and Mahāvīra it is Bhāskara II who actually gives and derives the correct expression for the volume and surface area of the sphere for the first time.

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*Attempta have been made by G. Matter and Kurt Elfening to re-interpret the verses concerned so as to yield correct expressions for the volume of a pyramid and the surface area (not volume) of a sphere. See "Rechenppennige" precented to Kurt Vogal on his 80th birthday, September 1968, pp. 57-68, The volume is obtained by cutting the sphere into pyramids with their apexes at the centre of the sphere and their bases of unit area on the surface. The surface area is got by dividing the surface into a number of lunes by lines passing through the poles of the sphere. Towards the end, the derivation seems to depend on an empirical method. In the later Āryabhaṭa school both these expressions are derived by the method of integration—the volume by cutting the sphere into thin circular laminas and the surface by cutting it into circular strips which are opened out as trapezia.

Arithmetic

The contributions of the Sanskrit world to the field of arithmetic are admittedly of deep significance. The decimal place value system together with the zero must have been perfected in India by the opening centuries of the Christian era. The earliest available record of the use of the zero is in Piṅgala's *Chandaḥ-sūtras* (c. 200 B.C.). In later centuries, the system reached the Arabs and through them Europe. The methods of long multiplication, division and extraction of roots which were rendered possible by this fundamental invention and which are more or less the same as our modern methods were so developed, by the time of the Jaina canonical works, as is indicated by the pronounced love of calculations carried out to minute fractions displayed by the Jainas. By the time of Brahmagupta at the latest a system of word numerals based on place value was in common use, whereas Āryabhaṭa I invented for use in his sine-table a system of letter numerals in which there were methods for indicating the tens, hundreds etc. The letter numerals of Āryabhaṭa II and of the later Āryabhaṭa school are entirely positional. The mathematical implications of zero and infinity were also understood in India by Brahmagupta's time. The Jainas recognised many kinds of infinity.

The rule of three or "Trairāśika", with its extension to the rule of seven, nine etc. popular in India from very early days is an Indian gift to the Arabs and to Europe. Problems of barter and exchange and mixtures are also dealt with comprehensively in Sanskrit texts.

Simple fractions are found used in the *Ṛgveda* and in the *Sulbasūtras*. The latter realized that a fraction of a unit of length will produce a unit of area which is numerically less then the unit of length, which means that the authors of the *Sulbasūtras* had gone beyond the concrete fact of multiplication and reached the abstract idea. In later arithmetical treatises the manipulation and simplification of different combinations of fractions forms a regular feature. The necessity for reduction to a common denominator before addition or subtraction is realized and practised as is shown by the works of Brahmagupta downwards and as is explained geometrically in the *Yuktibhāṣā* (16th cent.). Mahāvīra deals with the lowest common multiple, "Niruddha", and knows how to find it. He also gives a number of rules for expressing any fraction as the sum of a number of unit fractions.

P. Cajori and others have recognised the superiority of Indian methods of computation.

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Algebra

The achievements in algebra of Sanskritist India are also not unworthy. The *Śulbasūtras* worked out geometrically the linear equation—$ax=c^2$ in the course of the transformation of figures. They must also have, by combining and subtracting figures, come to realize that $(a\pm b)^2=a^2+b^2\pm 2ab$. So also, the irrationality of $\sqrt{2}$ seems to have been recognised. Early Jaina mathematics shows acquaintance with powers of numbers and the laws of indices. The *Uttarādhyayanasūtra* (c. 300 B.C.) speaks of varga (square), ghana (cube), varga-varga (4th power), ghana-varga (6th power), ghana-varga-varga (12th power) and the *Anuyogadvārasūtra* (c.1st cent.) speaks of 1st square, 2nd square, 1st square root, 2nd square root etc. It also notes,

$$a^{\frac{1}{2}}.a^{\frac{1}{4}}=(a^{\frac{1}{4}})^3$$

$$(2)^{2^5}\times(2)^{2^6}=2^{32}\times 2^{64}=2^{96},$$

and $a^{\frac{1}{4}}.a^{\frac{1}{8}}=(a^{\frac{1}{8}})^3$

i.e., it knows $a^m.a^n \quad a^{m\pm n}$

and $(a^m)^n=a^{mn}$

Jaina mathematicians had a special liking for the number two and its powers and fractions. Later Jaina texts like the *Trilokasāra* of Nemicandra (10th cent. A.D.) express numbers as powers of two, these powers being termed ardhaccheda (possibly meaning the number of times the number can be halved). Multiplication or division of numbers means the addition or subtraction of their ardhacchedas. If a number is to be raised to any power, the ardhaccheda of the number is to be multiplied by the power (*Trilokasāra* 105-107). Nemicandra nearly develops a logarithmic system with the base two.

Brahmagupta has a better system of expressing powers higher than four—'pañcaghāta' (fifth power), 'ṣaḍghāta' (sixth power) etc.

The algebraical elements, 'Bīja' or 'avyakta', and surds, 'karaṇi', were subjected to all the eight operations, 'parikarmāṣṭaka', which were done with rational numbers. The laws of signs were well understood. Sanskrit mathematical works were able, by the 7th century or earlier, to find a meaning for negative quantities through the opposition of directions. The quotient got by dividing any quantity by zero is termed 'khahara' (having zero as divisor) and is recognized to be infinite. The phrase 'yāvat-tāvat' and the names of colours like 'pītaka' (yellow), 'nīlaka' (blue) or their initial letters were used to indicate unknown quantities. Rudimentary symbolism for multiplication, addition, etc. existed. For the negative sign or the sign of subtraction, a cross (+) or a dot was used, whereas for the other operations, the initial letters of 'yuta' (for addition), 'mūla' (root) were used.

A fairly good system of writing equations was developed, the terms of the two sides being written in the same order of power one beneath the other. Solutions of quadratic equations were known to the authors of the *Śulbasūtras* and the early Jaina canonical works. By the time of Āryabhaṭa I and Brahmagupta, methods of solving linear equations in one or more unknowns and quadratic equations are known. Sporadic attempts to solve equations of higher degrees are made by Bhāskara II.

The most significant achievement of Indian algebra is in evolving methods for solving indeterminate equations of the first degree of the form $by - ax = \pm c$ (the method is called 'kuṭṭāka' or 'kuṭṭakara') and of the second degree of the form $nx^2 \pm 1 = y^2$ ('varga-prakṛti', square nature) and of the form $Nx^2 \pm c = y^2$: In this field India anticipates European mathematics by about ten centuries.

Permutations and Combinations

Permutations and combinations (termed 'vikalpa') was a favourite study with the Jainas. The *Bhagavatī Sūtra* (300 B.C) calculates the possible number of combinations that can be got out of a given number of fundamental philosophical categories, taken one at a time, two at a time, three at a time or more at a time-(Sūtra 314), and the groups that can be formed out of the sense organs. Such calculations are also found in the *Anuyogadvārasūtra* and the *Jambudvīpaprajñapti*. Correct results are invariably obtained through calculations based on the formulae

$${}_nC_r = \frac{n(n-1)\ldots\ldots(n-\overline{r-1})}{\underline{|r}}$$

$${}_nP_r = n(n-1)\ldots\ldots(n-\overline{r-1}).$$

Instances of perumutations and combinations are found in Hindu works of more or less the same period. Piṅgala's *Chandaḥsūtra*, which cannot be later than the 2nd century B.C., deals with the arrangement of short and long letters in metres. The *Suśruta Saṃhita* (earlier than Pāṇini) notes correctly that 63 combinations can be made out of the six 'rasas'.[3] Varāhamihira's (6th cent. A,D.) *Bṛhatsaṃhitā* contains examples of both permutations and combinations. Even if the earlier instances have been worked out by actually writing out the different groups ('prastāra') Varāhamihira who deals with problems resulting in large numbers of combinations must have been in possession of the general formula. This is stated for the first time by Mahāvīra (*Gaṇitasārasaṁgraha* VI. 326½). Brahmagupta might have dealt with it, but the Chandaścityuttarādhyāya of the *Brahmasphuṭa-siddhānta* has defied all attempts at elucidation till now and so nothing definite can be said. A tenth century commentator of Piṅgala's *Chandaḥsūtra*, Hemacandra, used a triangle of numbers ('meruprastāra') to arrive at the values of ${}_nC_1$, ${}_nC_2$, ${}_nC_3$, etc. easily, Small squares are to be drawn as in the figure so as to form a triangle. One is to be written down in the first square, In the rest of the squares the sum of the numbers in the two squares immediately above them are to be written. Then the rth row gives the values of ${}_rC_1, {}_rC_2, {}_rC_3 \ldots, {}_rC_n$ in order. This diagram is similar to Pascal's Triangle, but much simpler. The commentator himself is six centuries earlier than Pascal, and he claims the rule is contained in Piṅgala's own sūtras. The sūtra in question,[4] very concise and elliptical, cannot be understood without the help of a commentary. Verse 22, ch. 77, of the *Bṛhatsaṃhitā* seems to contain the same rule for forming the Meruprastāra triangle.

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[3] Srinivasa Iyengar, C. N. 'The History of Ancient Indian Mathematics', p. 27,

1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1

The first systematic treatment of combinations is by Mahāvīra. Bhāskara II deals with both combinations and permutations. But neither of these mathematicians refer to Meruprastāra. By the time of Bhāskara, permutations and combinations of digits in forming numbers seem to be the chief interest, though the number of images of deities with different combinations and permutations of characteristics weapons is dealt with. This shift of interest must be responsible for the shift in the nomenclature. What was 'vikalpa' (sometimes 'bhaṅga') to the Jainas and Varāhamihira becomes 'Aṅkapāśa' in Bhāskara and Nārāyaṇa Paṇḍita. Nārāyaṇa elaborates a variety of 'prastāras', but does not give Halāyudha's 'Meruprastāra.

By the end of the early Jaina period we got the Bakhshali manuscript which bears witness to considerable development in algebra and arithmetic during the 2nd century A.D. and earlier. Fair advancement in the manipulation of complex fractions and surds is seen. The approximation formula, *viz.*,

$$A = a + \frac{r}{2a} - \left(\frac{r}{2a}\right)^2 ,$$

for the value of a surd is familiar and frequently passed into use, Moreover, an elaborate method for estimating the error in the various orders of approximations.

Series Mathematics and Integration

A very significant but little known achievement of Sanskritic mathematics is the discovery of integration by the summation of power series and its application to different problems. It was the astronomical need of knowing the circumference, chords and arcs of a circle accurately that led to the perfection of this tool. But behind the achievement lies the long and sustained interest in series of the Indians. In the *Taittirīya Saṃhitā*[5] and in the *Vājasaneyi Saṃhitā*[6] we get number series in arithmetic progression and in the *Pañcaviṃśa Brāhmaṇa* the geometrical progression 12, 24, 48, 96....196-608, 393-216, In the *Bṛhaddevatā* the sum of the natural numbers from 2 to 1,000 is correctly given. The Jaina cosmography and accounts of hells and heavens contain many instances of Arithmetic Progressions and Geometrical

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[4] Pingala's '*Chandaḥsūtra*', VIII, 34.
[5] *Taittirīya Samhitā*, VII, 2, 12, 17.
[6] *Vājasaneyī Samhitā*, XVIII, 24, 25.

Progressions. In the context of the pronounced love of calculations of the Jainas it is quite likely that the early progress in series mathematics is entirely due to them. Later works like the *Trilokasāra* and *Gommaṭasāra* enumerate many different kinds of series ('dhara'). The commonly used word for series. 'śreḍhi' is etymologically obscure. May be it is a Prakritization of 'śreṇi' effected by the Jainas from whom the word was re-accepted into Sanskrit.

Outside Jaina literature, the Bakshali manuscript is quite at home with the series. Simple Arithmetical Progressions and Geometrical Progressions, even complex series in the form of

1. $t_1 + (t_1 r + dt_1) + \{t_1 r^2 d(t_1 \pm t_1 r)\} + \{t_1 r^3 \pm d(t_1 + t_1 r + t_1 r^2)\} \pm \cdots\cdots\cdots$
2. $t_1 + (2t_1 + b) + \{3(t_1 \pm t_2) \pm (b + d)\} \pm \{4(t_1 \pm t_2 \pm t_3) \pm (b \pm 2d)\} \pm \cdots\cdots\cdots$

etc., are found in this fragmentary work.

Āryabhaṭa I gives the sum of the natural numbers, of the triangular number ('saṁkalita-saṁkalita') and of the squares and cubes of the natural numbers. We do not know how the last three were summed up. The later Āryabhaṭa school gives geometrical demonstrations for the results. Was the mode of arriving at the results also geometrical? Mahāvīra extends these results to cover any series in Arithmetical Progression and also gives examples of complex series reminiscent of Bakshali mathematics,

The first instance of the summation of a geometrical progression or rather finding out the nth term (from which the sum of n—1 terms can be easily found) is found in Piṅgala's *Chandaḥsūtra* in connection with finding the number of metres of one letter, two letters, three letters etc., in a line. An easy method for finding the value of r^n is given which is reproduced by Mahāvīra centuries later.

It is Mahāvīra who for the first time gives a systematic treatment of geometrical progressions. He knows that the sum of a geometrical progression with 'a' as first term, 'r' as common ratio and 'n' as period is $\frac{ar^n - a}{r - 1}$ and how the formula is to be derived. In the Bakshali manuscript and the *Gaṇitasārasaṃgraha* of Mahāvīra, arithmetical progressions with fractional periods occur, in the former in isolated problems, but in the latter as a feature of a regular topic 'bhinnasaṁkalitam' (summation of fractions). But geometrical progressions with fractional periods are never found. Mahāvīra also sums up arithmetico-geometrical series like,

$$a \pm (ar \pm m) \pm \{(ar \pm m)r \pm m\} + [\{(ar \pm m)r \pm m\}r \pm m] + \cdots\cdots$$

His methods of splitting the number one into a regular series of unit fractions is an exercise in geometrical progressions. Though the last named are convergent series, Mahāvīra does not seem to deal with an infinite convergent series as Vīrasena earlier does in his derivation of the volume of a cone frustum. Nīlakaṇṭha (15th cent.) also has recourse to the summation of an infinite convergent series while deriving a good approximation formula for the arc 'a' in terms of the chord 'C' and height 'h', *viz.*, $a = \sqrt{(1 + \frac{1}{3})h^2 + c^2}$. The Indian mathematicians were aware latest by the 9th century that an infinite convergent series has a finite sum. Nīlakaṇṭha also gives a fine logical explanation why this is so (*Āryabhaṭīya-bhāṣya*, p. 106),

Nārāyaṇa (14th cent.) takes a significant step forward in series mathematics when he extends the 'saṃkalita-saṃkalita' of Āryabhaṭa I to summation of any order. The sum of the first 'n' natural numbers repeated 'r' times will be

$$\frac{n(n+1)(n+2)\ldots\ldots\ldots(n+r-1).}{\underline{|r}}$$

By the end of the 14th century or earlier, the summation of regular series acquired a new meaning when it was applied to the summation of the infinitesimally small parts of a whole and thus became integration. This was done for the first time by Mādhava of Saṁgamagrāma (14th cent.) for calculating the circumference of a circle from its radius. An infinite series for π or rather the circumstances is obtained thus:

$$\text{circumference}=8R(L-\tfrac{1}{3}+\tfrac{1}{5}-\tfrac{1}{7}+\ldots\ldots).$$

In the course of its derivation many integrals of the powers of a quantity and the results of repeated integration are proved and used. These are

$$\int_0^x x = \frac{x^2}{2}$$

'vargasaṃkalita' $\int_0^x x^2 = \frac{x^3}{3}$

'ghanasaṃkalita' $\int_0^x x^3 = \frac{x^4}{4}$

'vargavargasaṃkalita' $\int_0^x x^4 = \frac{x^5}{5}$

and $\int_0^x x^n = \frac{x^{n+1}}{n+1}$

and 'Dvitīyasaṃkalita' $\int_0^x\int_0^x x = \frac{x^3}{\underline{|3}}$

'tṛitīyasaṃkalita' $\int_0^x\int_0^x\int_0^x x = \frac{x^4}{\underline{|4}}$

'anekavargasaṃkalita' or nth order integral of 'x' $= x\,\frac{x^{n+1}}{\underline{|n+1}}$

From the series for π, by suitable manipulation many other infinite series for π are obtained. Gregory's general series for arc tan t is obtained in the form

$$\text{arc} = \frac{sR}{c} - \frac{sR}{3c^{\circ}}\frac{s^2}{c^2} + \frac{sR}{5c^{\circ}}\frac{s^4}{c^4} - \ldots\ldots\ldots\ldots$$

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The reasoning is the same as that for the series for the circumference. Similarly with the help of the new-found tool of integration and subtle reasoning, the infinite series for sin θ and cos θ (actually R sin θ and R cos θ) are derived (*Yuktibhāṣā* pp. 183-194) which, since the Indian deals with the sine chords and cosine chords instead of the ratios, take the form,

$$\text{the `ardhajyā' } (R \sin\theta) = a - \frac{a^3}{R^2.\underline{|3}} + \frac{a^5}{R^4.\underline{|5}} - \frac{a^7}{R^6.\underline{|7}} + \cdots\cdots\cdots$$

$$\text{the `koṭijyā' } (R \cos\theta) = R - \frac{a^2}{R.\underline{|2}} + \frac{a^4}{R^3.\underline{|4}} - \frac{a^6}{R^5.\underline{|6}} + \cdots\cdots\cdots$$

('a' is the arc and 'R', the radius).

These, when the arc is expressed in radians, become equivalent to

$$\sin\theta = \theta - \frac{\theta^3}{\underline{|3}} + \frac{\theta^5}{\underline{|5}} - \frac{\theta^7}{\underline{|7}} + \cdots\cdots\cdots$$

$$\cos\theta = 1 - \frac{\theta^2}{\underline{|2}} + \frac{\theta^4}{\underline{|4}} - \frac{\theta^6}{\underline{|6}} + \cdots\cdots\cdots$$

The volume and surface area of a sphere are also correctly derived using the same tool of integration. All this we know from the *Yuktibhāṣā* (16th cent.), a mathematical treatise allegedly expounding the mathematics in the *Tantrasaṁgraha* of Nīlakaṇṭha Somayājin (15th cent.) and an anonymous and undated commentry on the *Līlāvatī* named *Kriyākramakarī*, written probably by Śaṅkara Vāryār, a pupil and commentator of Nīlakaṇṭha. The series for π, the arc, and for the cosine and sine are found besides in the *Tantrasaṁgraha*, the *Karaṇapaddhati*, and the *Sadratnamālā*. The latter two are later than the *Yuktibhāṣā* and the *Kriyākramakarī*. The expository texts, the *Yuktibhāṣā* and the *Kriyākramakarī*, assign these results to Mādhava of Saṃgamagrāma.

Integration by fluxions was discovered and used in India at least two and a half centuries earlier than Newton and Leibnitz.

Geometrical Algebra

Another feature of Indian mathematics which attained its highest growth in the later Āryabhaṭa school is what can be termed geometrical algebra. This is a direct inheritance from the *Sulbasūtras* which arrived geometrically at the identities $(a\pm b)^2=a^2+b^2\pm 2ab$.

But the influence of the geometrical algebra found in the works of the Arab al-Khowarizmi (c. 825 A.D.) and Omar Khayyam (c. 1110), though not apparent, cannot be ruled out. They also evaluated geometrically simple surds as well as those of the form $\sqrt{a^2+b^2}$; $\sqrt{a^2-b^2}$. Throughout the ages, geometrical demonstration must have been used for validating algebraical truths though this being meant for the edification of the direct pupils is usually left out of the texts. Bhāskara's commentators, Gaṇeśa and Kṛṣṇa, give us a few examples of diagrammatic demonstrations, namely those for $a^2-b^2=(a+b)(a-b)$ and

$(a+b)^2-a^2-b^2=2ab$, and a geometrical method for solving the indeterminate equation, $ax+by+c=xy$

Bhāskara I (7th cent.) offers a geometrical explanation for $\frac{1}{4}\cdot\frac{1}{5}=\frac{1}{20}$. In the later Āryabhaṭa school this method is ably and extensively used. The *Yuktibhāṣā* (pp. 183-194) explains the operations of multiplication and division diagrammatically. The necessity for reducing fractions to a common denominator before they are added or subtracted is also geometrically explained. The identities,

$$(a+b)^2=a^2+b^2+2ab$$
$$(a+b+c)^2=a^2+b^2+c^2+2ab+2bc+2ca$$
$$4ab=(a+b)^2-(a-b)^2$$

are proved diagrammatically.

The *Kriyākramakarī* elaborates a whole list of demonstrations for different equalities and ascribes these to a mathematician, Citrabhānu. Examples are—

$$(1)\quad \frac{a^3-b^3-(a-b)^3}{3(a-b)}=ab$$

$$(2)\quad \frac{a^3-b^3-(a-b)^3}{3ab}=a-b$$

and

$$(3)\quad \frac{2(a-b)+(a-b)}{3(a^2+b^2)}=a-b.$$

More interesting is the graphical proof for the lemma in the *Līlāvatī* that $a^2\pm b^2-1$ will be a perfect square if $a=8p^4+1$ and $b=8p^3$ (where 'p' is any arbitrary number). The expressions for the sums of arithmetic and geometric progressions are also diagrammatically validated. The practice of representing arithmetic progressions diagrammatically is old. Śrīdhara (10th cent.) and Nārāyaṇa (14th cent.) represent arithmetical progressions by trapezia while the later Āryabhaṭa school represents them by a pile of as many rectangular strips as there are terms in the series. The *Kriyākramakarī* demonstrates by two-dimensional and three-dimensional representations the truth of the expressions for (1) the sum of the natural numbers, (2) the sum of the triangular numbers, (3) the sum of the squares of the natural numbers, and (4) the sum of the cubes of the natural numbers. These methods of demonstration have the merit of being immediately convincing and can be used with profit in schools. According to the *Kriyākramakarī*, the formulae for the sums of the higher orders of triangular numbers can also be demonstrated similarly.

Trigonometry

The branches of mathematics in which India has influenced world mathematics most are arithmetic and trigonometry. The world owes the basic concepts of trigonometry, the sine and cosine ratios to Sanskritic India. While Ptolemy had used a table of chords for astronomical calculations, the early Indian Siddhāntas and Āryabhaṭa I have a table of half-chords or sine-chords, called in Sanskrit 'ardhajyā', 'jyā' or 'jīva'. The last term, becoming 'jaib' in Arabic, gave rise to the Latin translation 'sinus'. The versed sine-chord and the cosine-chord ('koṭijyā') also were used quite early, Āryabhaṭa's table of sine-differences for a radius $\frac{360\times60}{2}$ is quite accurate except in two places. The *Pañcasiddhāntikā* gives a theoretical method based on trigonometrical identities for compiling the sine-table and implies the knowledge of the solution of right spherical triangles. Bhāskara I (7th cent.) gives the formula

$$R\sin\theta=\frac{4R\theta\ (180-\theta)}{40{,}500-\theta(180-\theta)}$$

for finding the sine of any arc without the use of the sine-table. Brahmagupta in the same century has a formula for second order interpolation which is the equivalent of the modern Newton-Sterling formula. He was also familiar with the sine-rule and cosine-rule as applicable to the plane triangle. The *Siddhānta* of Vaṭeśvara (904 A.D.) contains new identities like

$$\sqrt{2\ \text{vers}\ \theta-\text{vers}^2\ \theta}=\sin\ \theta$$

$$\frac{\sin^2\theta}{\text{vers}\ \theta}+\text{vers}\ \theta=2$$

Muñjāla in the same century knows that $d(\sin\theta)=\cos\theta.d\theta$. Āryabhaṭa II and Bhāskara II have a rule for finding the instantaneous motion of a planet which implies the use of the same formula. Bhāskara II's *Jyotpatti* contains in addition new identities including the sum-and-difference theorem for sines, which is known as Jyābhāvanā. This sum-and-difference theorm is famous in the Later Āryabhaṭa school as जीवेपरस्परन्याय and was discovered by Saṃgamagrāma Mādhava. It is supplied with a geometrical proof. Bhāskara II also knows

$$R\ \sin\ 18^\circ=\sqrt{\frac{5R^2-R}{4}}$$

$$\text{and } R\ \sin\ 36^\circ=\sqrt{\frac{5R^2-\sqrt{5R^4}}{8}}$$

Mādhava's discovery of the sine and cosine infinite series and Gregory's series has already been mentioned. Besides, he has discovered methods for higher interpolation in the sine table which are equivalent to the modern Taylor Series approximations. These techniques were improved and diversified by his successors Parameśvara, Nīlakaṇṭha and others With the help of the infinite series for π, sine and cosine and highly efficient methods (based on the theory of limits) of applying corrections to the sums of such series, Mādhava calculated the values of the 24 tabular sines in degrees, minutes and seconds to an amazing degree of accuracy Nīlakaṇṭha, his worthy follower, proves geometrically that

$$d\ (\sin\ \theta)=d\theta.\cos\ \theta$$
$$d^2\ (\sin\ \theta)=-d\theta,\ \sin\ \theta$$

and solves the spherical triangle fully. The *Yuktibhāṣā* written in Malayalam but inspired by and modelled on Sanskrit works, gives elaborate proofs for Mādhava's infinite series for π, arc $\tan^{-1}x$ and the sine and cosine series, as also the trigonometrical identities,

$$\sin\ (A\pm B)=\sin A.\ \cos B\pm\cos A.\ \sin B$$

$$\text{and } \sin^2 A-\sin^2 B=\sin\ (A+B).\ \sin\ (A-B)$$

The *Siddhāntatattvaviveka* of Kamalākara (1658) which shows the influence of Arab mathematics contains the formulae for the expansion of multiple arcs 2A, 3A, 4A and 5A and of the sub-multiple arcs A/2, A/3, A/4 and A/5 along with the proofs.

This survey shows that Sanskrit and India had some significant contributions to make to diverse branches of mathematics like geometry, arithmetic, algebra, trigonometry, series mathematics, permutations and combinations, theory of numbers and calculus. One peculiarity of Sanskrit mathematical texts, already much maligned, is that they record the results without proof of derivation. But this need not, and does not, mean that proofs were not sought or found. The records that have come down to us are mostly of the nature of summaries of the lessons given by teachers to students, couched in verse for easy memorising. Hence the methods of derivation, proofs and rationales were generally left out, the results and lemmas only being recorded. A few rationales and modes of derivation occur in some commentaries, as in Bhāskara's own *Vāsanā* commentary of his *Siddhānta Siromaṇi*. Proofs were almost a must in the commentaries produced by the Āryabhaṭa school, like Nīlakaṇṭha's *Āryabhaṭīyabhāṣya* and the anonymous *Kriyākramakarī* on the *Līlāvatī*. The *Yuktibhāṣā* in Malayaḷam, though an independent work, is written as an aid to the understanding of Nīlakaṇṭha's *Tantrasaṁgraha* and so gives many rationales and proofs, many of which are found in the *Kriyākramakarī* too. A systematic derivation of the infinite series for π, the sine, the cosine and the expressions for the volume and surface area of a sphere are the most noteworthy of these. Proofs for Brahmagupta's theorems, the sum-and-difference theorem for sines and other trigonometrical identities are also worked out. Sometimes commentaries are attempted by non-mathematicians and such commentaries seldom give rationales and sometimes give mistaken ones too.

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SOME NEW MATHEMATICAL FACTS IN ANCIENT HINDU ASTRONOMY

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1. There were many noteworthy points both in ancient Hindu Mathematics as well as in ancient Hindu Astronomy which have not so far received proper elucidation. A few of these are sought to be elucidated in this paper.

2. *Brahmagupta's Contribution to Mathematics*: Brahmagupta was a very ancient Mathematician and Astronomer who wrote his *Brahma Sphuṭa Siddhānta* in 628 A.D. His work was accorded 'Āgama-pramāṇa' even by Bhāskara II, a mastermind. He discovered some formulae connected with the cyclic quadrilaterals, as recognized by Hobson in his Trigonometry. Besides, in what is called 'Vargaprakṛti', an algebraical analysis of the 2nd degree indeterminate equations he *may be claimed as a precursor of Demoivre* who discovered the famous theorem which goes by his name. It may be mentioned that Demoivre wrote about ten centuries later. The following is an illustration. 3, 4, 5 are called a Pythagorean set of numbers because $3^2+4^2=5^2$. 5,12,13 is another set since $5^2+12^2=13^2$. From these two sets, by what Brahmagupta calls Samāsa Bhāvana, a third Pythagorean set is derived as $(3\times12+4\times5)$, $(4\times12-3\times5)$, 5×13 i.e., 56, 33, 65 i.e., $56^2+33^2=65^2$. Cross-multiplication implied in $(3\times12+4\times5)$ is termed Vajrābhyāsa, since a diamond is known to be cut cross-wise. If the two initial sets were identical as 3, 4, 5 then the derivation of the set $(3\times4+3\times4)$,

3, 4, 5

$4\times7-3\times7$, 5×5 i.e. 24,7,25 is called Tulyabhāvana. Given the two sets 56,33, 65; 5, 12,13, derivation of the set 3,4,5 is called Antara-Bhāvana. The Samāsa-Bhāvana given above is just a different version of $(\mathrm{Cos}\,\partial+i\,\mathrm{Sin}\,\partial)\,(\mathrm{Cos}\,\beta+i\,\mathrm{Sin}\,\beta)=\mathrm{Cos}\,\overline{\partial+\beta}+i\mathrm{Sin}\,\overline{\partial+\beta}$ which led Demoivre to postulate his theorem. In other words, writing the two initial sets as $\frac{}{5}, \frac{4}{5}, \frac{5}{5}$ and $\frac{5}{13}, \frac{12}{13}, \frac{13}{13}$

$$\text{i.e.}\ \left.\begin{matrix}\frac{3}{5}, & \frac{4}{5}, & 1\\ \frac{5}{13}, & \frac{12}{13}, & 1\end{matrix}\right\}\ \text{Obtaining}\ \frac{56}{65}, \frac{33}{65}, 1\ \text{or, } 56, 33, 65$$

is the same thing as taking Sin A Cos A, 1 and getting
Sin B, Cos B, 1

(Sin A Cos B+Cos A Sin B), (Cos A Cos B—Sin A Sin B), 1 ie. $\mathrm{Sin}\,\overline{A+B}$, $\mathrm{Cos}\,\overline{A+B}$, 1. Thus using Tulya-Bhāvana n times we have from $\mathrm{Sin}\theta$, $\mathrm{Cos}\theta$, 1, the set $\mathrm{Sin}\,n\theta$, $\mathrm{Cos}\,n\theta$, 1, which is another version of $(\mathrm{Cos}\theta+i\mathrm{Sin}\,\theta)^n=\mathrm{Cos}\,n\,\theta+i\mathrm{Sin}\,n\,\theta$ only without using 'i' where $i^2=-1$. Hence Brahmagupta's Bhāvana-method

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is only Demoivre's theorem in the case of a positive integral exponent. Demoivre's achievement was to extend the theorem to the negative and fractional indices. These concepts of 'Bhāvana' led the ancient Hindu Mathematicians to a very sophisticated algebraical analysis of the 2nd order indeterminate equations, under the name varga-prakṛti or 'Nature of the square'. In this analysis the highest point was attained by Bhāskara or a little prior to Bhāskara, who gave what is called 'the method of cakravāla', in the words **"चक्रवालमिदं जगुः"**. Many hold that Bhāskara evolved this cakravāla method and out of modesty used the word 'jaguh'. The beauty in this method of cakravāla can very well be noted when it is stated that a problem set and solved by Bhāskara was exactly the problem thrown out as a challenge to be solved, by the mathematician Fermat to another named Frenicle. Whether Fermat had the solution of the problem up his sleeve, we are not aware but as late as 1787, no less a mathematician than Lagrange had to explain the theory in his memoir for the first time which was six centuries after Bhāskara or even more. Many problems set and solved by Bhāskara in this Vargaprakṛti, indicate what heights were reached by the Hindu genius long before the thread was resumed in the West.

3. *Astronomy*—In the branch of Astronomy far more ground was covered in ancient India. The following examples illustrate the ancient Hindu genius in this field.

3. (*a*) To find the latitude of a place by just one observation of the gnomonic shadow of the Sun on a given date. Bhāskara gives the method in verses 77, 78 Tripraśna, Gaṇitādhyāya as **"क्रान्तिज्याकर्णवधात्"** etc. which means-

Let Laghu $= L = \left(\frac{KHSin\partial}{R}\right)^2$; Adya $= A = \frac{12^2\,(\text{Laghu} - b^2)}{\text{Laghu} \sim 12^2}$;

Para $= P = \frac{12^2 b}{\text{Laghu} \sim 12^2}$, then the equinoctial shadow s is given by

$s = \sqrt{P^2 + A} \pm P$ where H Sin∂ = Hindu sine of declination of the Sun, b = chāyābhuja, and the gnomon's length is 12 units.

The modern proof could be given as follows. Let the zenith-distance of the Sun be Z; the gnomon's shadow be S; and the Chāyākarṇa = K where K is the hypotenuse of the triangle with the gnomon and its shadow as the other two sides.

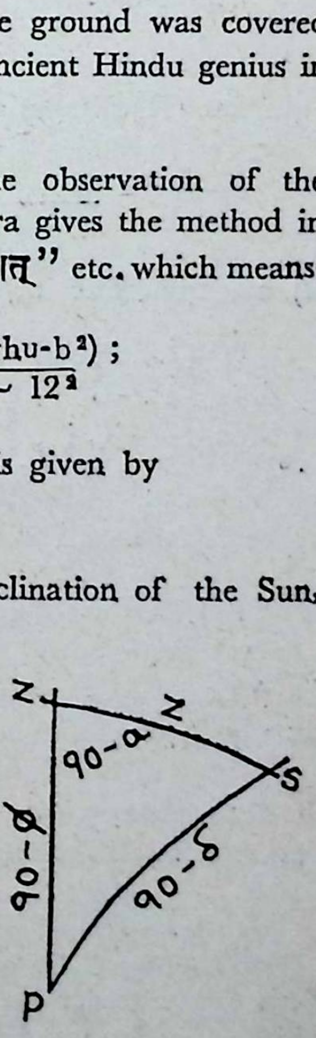

Fig. 1

This means $\frac{KHC\hat{}sZ}{R} = 12$; $\frac{KHSinZ}{R} = S'$. Now from the spherical triangle PZS, where P = celestial pole;

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Z=Zenith; S=Sun, $\text{Sin}\,\partial=\text{Sin}\,\phi\ \text{Cos}\,Z+\text{Cos}\,\phi\ \text{Sin}\,Z\ \text{Sin}\,a$ (1) where ϕ =latitude of the place; ∂=declination of the Sun, a=the Hindu azimuth of the Sun measured from the east point. $\therefore K\ \text{Sin}\,\partial=\text{Sin}\,\phi\ K\ \text{Cos}\,Z+\text{Cos}\,\phi\ K\ \text{Sin}\,Z\ \text{Sin}\,a$.

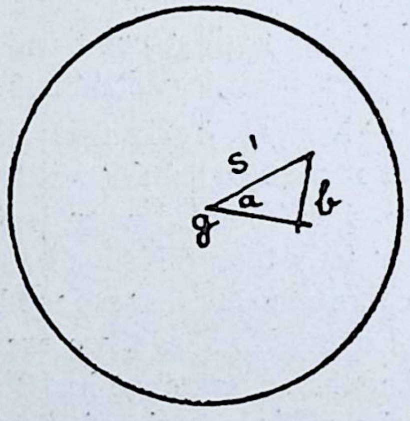

Fig. 2

From Fig. 2, $S'=K\ \text{Sin}\,Z$, $b=K\ \text{Sin}\,Z\ \text{Sin}\,a$

Also $\tan\phi=\frac{s}{12}$ $\quad\therefore \text{Sin}\,\phi=\frac{s}{\sqrt{s^2+12^2}}$ $\quad \text{Cos}\,\phi=\frac{12}{\sqrt{s^2+12^2}}$

Equation (1) assumes the form

$$K\,\text{Sin}\,\partial=\frac{K\,H\sin\partial}{R}=\sqrt{L}=\frac{12s}{\sqrt{s^2+12^2}}+\frac{12b}{\sqrt{s^2+12^2}} \quad (2)$$

(2) is a quadratic in 's' which may be written

$$\frac{s^2+2\cdot 12^2\cdot bs}{12^2-L}=\frac{12^2(L-b^2)}{12^2-L} \quad \text{i.e. } s^2+2Ps=A$$

$\therefore s=\sqrt{P^2+A}+P$ if bs be +ve and if negative its value will be $\sqrt{P^2+A}-P$ as given by Bhāskara. Bhāskara proves it by using the famous Hindu formula $A=s+b$ where A is known as Karṇāgrā.

3.(*b*) In this context it is worth noting that the modern spherical trigonometrical formulae (1) $\text{Cos}\,Z=\text{Sin}\,\phi\ \text{Sin}\,\partial+\text{Cos}\,\phi\ \text{Cos}\,\partial\ \text{Cos}\,h$ and (2) $\text{Sin}\,\partial=\text{Sin}\,\phi\ \text{Cos}\,Z+\text{Cos}\,\phi\ \text{Sin}\,Z\ \text{Sin}\,a$ appear in Hindu Astronomy in a different garb namely Iṣṭa Śaṅku$=\frac{12}{K}\times$Iṣṭa-Hṛti and $A=s+b$ resply. For this correlation, the reader may please refer to the Ph.D. thesis of the author *A critical study of the Ancient Hindu Astronomy* published by the Karnatak University (1970).

3. (*c*) *Agrāntara Correction*—This is a correction made to rectify the east-west line got by morning and evening gnomonic shadows as mentioned in the *Sulba-Sūtras* under the name 'Prācī-sādhana' required to orient the Yajñaśālā. This correction was first given by Śrīpati (1039 A.D.). It shows to what an extent of accuracy the procedure was developed, in as much as the correction is so minute

that it could have been even overlooked. Bhāskara gives it in verse 8, Tripraśna, Gaṇitādhyāya as "वृत्तेऽम्भरसुसमीकृतक्षितिगते" etc. which means the correction is equal to $\frac{K\triangle(\text{Sin}\partial)}{\text{Cos}\phi}$. We can prove this in modern symbolism as follows.

Since both the morning and evening shadows equal the radius of the horizonta gnomonic dial, both the Zenith distance and the chāyākarṇa are constant. Hence in the formula $\text{Sin}\partial = \text{Sin }\phi \text{ Cos Z} + \text{Cos }\phi \text{ Sin Z Sin}a$ multiplying by K and taking the differentials,
$(K\triangle\text{Sin}\partial) = \triangle(K \text{ Sin Z Sin}a). \times \text{Cos }\phi \therefore \frac{K\triangle(\text{Sin}\partial)}{\text{Cos }\phi} = \triangle$ (Bhuja)

as is given by Bhāskara. Since the variation in ∂ between the morning and evening observations is small, the correction is very small numerically. Bhāskara's proof is most simple, because $A = s + b$, $\because \partial A = \partial b \therefore \frac{\partial(K \text{ Sin}\partial)}{\text{Cos }\phi} = \partial b$.

3.(*d*) *Iṣṭa dik-chayānayana*—Bhāskara gives this method in verses 46, 47 Tripraśna, Gaṇitādhyāya in the words "पलप्रभा व्यासदलेन निघ्नी" etc. The problem is to find the length of the gnomonic shadow on any day in any direction. Bhāskara says: "Assume $\frac{Rs}{H\text{Sin}a}$ to be the equinoctial shadow where 's' is the original equinoctial shadow and 'a' the Hindu azimuth. Compute therefrom H Sin L where L is the hypothetical latitude. Also compute another quantity 'D' where $H \text{ Sin } D = \frac{H\text{Sin } L. \ H \text{ Sin}\partial}{H \ \text{Sin}\phi.}$ Then $12 \ (L \pm D)$ gives the shadow required." We shall prove this using modern symbolism. From Figures (3) and (4) wherein PZS is the spherical triangle previously cited and TRQ the celestial equator, the Zenith-distance $ZS = ZT \pm ST$ according as the Sun is on the south or north of the equator. ZT is the Zenith-distance of the Sun when he is on the equator having the same azimuth. ST is construed as the increase or decrease therein on account of the declination. In other words, keeping the azimuth constant, the Zenith-distance is viewed as a function of ϕ and ∂. When the declination is Zero, the Z.d. (zenith-distance) is ZT, looked upon as the contribution of ϕ, and is signified by L. Then ST is viewed as the contribution of ∂ and is denoted by D. Thus $Z.d = L \pm D$ and since the gnomonic shadow is 12 tanZ, the required shadow is 12 tan $(L \pm D)$. One really wonders at Bhāskara's ingenuity in the above functional concept. We shall now find L and D. From $\triangle$PZT, Cos 90=

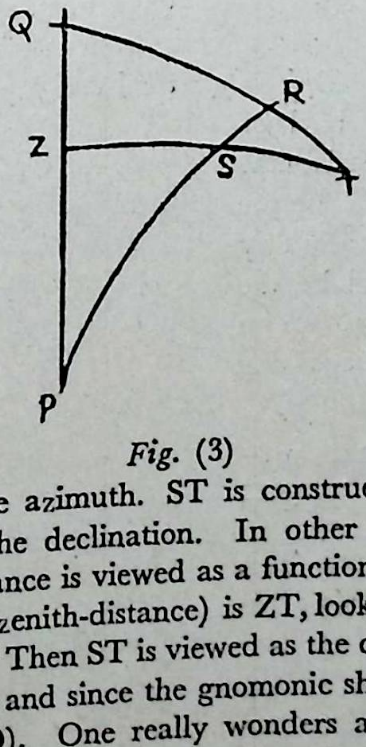

Fig. (3)

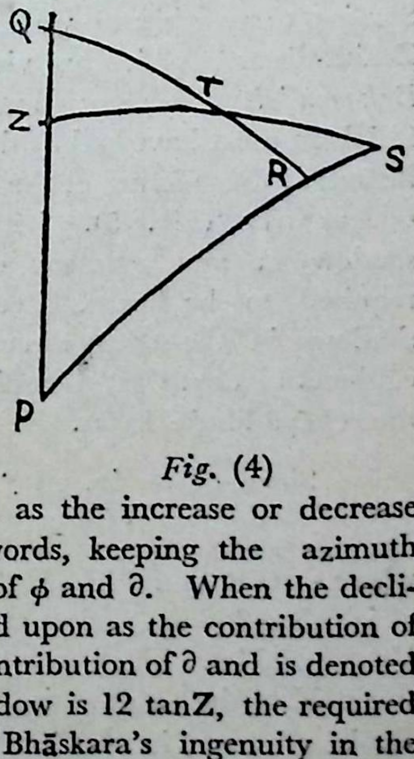

Fig. (4)

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CosZTSinϕ+Sin ZT CosϕSina whence tan ZT$=\frac{\tan\phi}{\text{Sina.}}$ But tan ZT$=\frac{S_1}{12}$, tan$\phi=\frac{s}{12}$

where S_1 and s are respectively the gnomonic shadows when the Sun is at T and Q.

$$\therefore \frac{\tan ZT}{\tan\phi} = \frac{S_1}{s} = \frac{1}{\text{Sina}} = \frac{R}{\text{HSina}} \qquad \therefore S_1=\frac{Rs}{\text{HSina}}$$

We are asked to compute the HSine of that hypothetical latitude taking S_1 as the equinoctial shadow, which means we are asked to compute Sin ZT which is Sin L. From this L can be had. Also from triangles ZTQ, STR, if Z$\hat{T}$Q=i, Sinϕ= Sin i Sin ZT; Sin∂=Sin i SinST.

$$\therefore \text{SinST}=\frac{\text{Sin}\partial}{\text{Sin}\phi}.\ \text{SinZT i.e. SinD}=\frac{\text{Sin}\partial}{\text{Sin}\phi,}.\text{Sin L.}$$

i.e. HSinD $=\frac{\text{HSin}\partial}{\text{HSin}\phi.}$ H SinL as is directed by Bhāskara to get the value of D. The directive " ताभ्यां दिनार्धद्युतिवत् विदध्यात् " means computing 12 tan (L±D) where L and D are the hypothetical Akṣajyā and the corresponding hypothetical Krāntijyā. 12 tan (L±D) hence gives the shadow required. It is to be noted that Bhāskara named HSinL as Iṣṭa-Akṣajyā or Dṛk-maṇḍala-akṣajyā, and HSin D as the Dṛk-maṇḍala Krāntijyā, the very conception of which is really ingenious. This means, just as when the Sun is on the meridian, ϕ and ∂ are the arcs of the meridian, similarly when the Sun is on any arbitrary vertical or Dṛk-maṇḍala, the segments ZT and ST of the Zenith-distance which are viewed as the contributions of ϕ and ∂ are termed as *Dṛk-maṇḍalīya-akṣajanya* and *Dṛk-maṇḍalīya-krānti-janya.* In conceiving this Bhāskara must have had at the back of his mind, the picture of the horizontal dial as well (Fig. 5). Let gK be the shadow at any moment on any day required to be found. Let gl be the shadow in the same direction on an equinoctial day. On an equinoctial day the chāyā-bhuja lq=s.

$$\text{Since gl} = \frac{\text{lq. gp}}{\text{PM}} \therefore \text{gl}=\frac{\text{Rs}}{\text{H Sina}}$$

where gp=R and PM=H Sina. This gl is called by Bhāskara as Iṣṭa-Dṛk-Vṛtta-palabha. The remaining segment lK of the shadow is due to the Sun's advance in ∂. Then the computation of lK is dictated from figures (3) & (4),

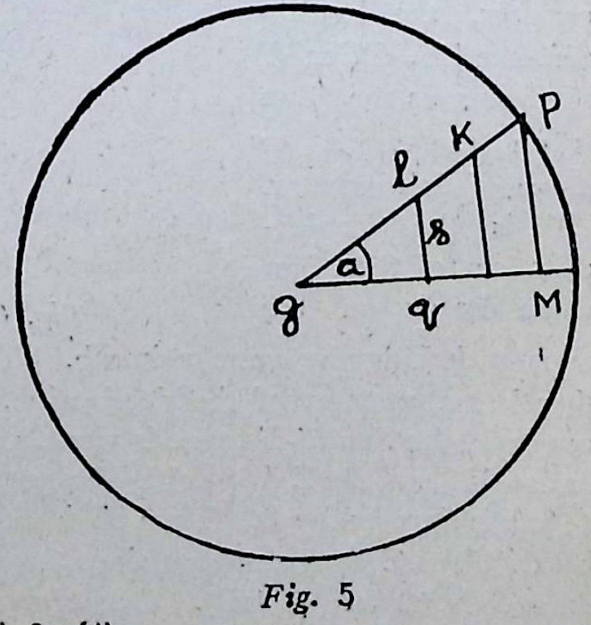

Fig. 5

3.(*e*) *Retrograde motion of planets*—Bhāskara gives the true motion of a planet in verse 39, Spaṣṭādhikāra, Gaṇitādhyāya as "फलांशखाङ्कान्तरशिञ्जिनीघ्नीं etc"

i-e $u-\frac{(u-v)HCos\theta}{K}$ where u, v are respectively the mean motions of the

Śīghra and the planet, θ=Śīghraphala and K=Śīghrakarṇa. We shall first give Bhāskara's proof, to show what a critical eye he had in not only conceiving the geometrical picture but also the instantaneous motion which credits him with the title 'The precursor of Newton in the concepts of differential calculus'. Let (ε_1) (Fig. 6) represent the Kakṣāmaṇḍala, the mean orbit of the planet with the Earth ε_1, as its centre. Let (ε_2) be the prati-maṇḍala or the eccentric in which the mean planet is taken to move actually and not the true planet as is interpreted by some. It may be mentioned here and now that the true planet was never taken by the Hindus to move in a circle, in as much as the true position of the planet was taken to be the point of intersection of the Karṇa and the Kakṣāmaṇḍala and this true position though apparently is presented to be on the Kakṣāmaṇḍala the actual angular velocity which it is that matters does not depict circular motion which should be uniform. As a matter of fact, the form of the equation of Centre namely 2eSin m clearly secures ellipticity in the orbit of a planet.

Now, let P_1, P_2 be the *mean* positions of the planets in the pratimaṇḍala on two consecutive days *with respect to the Ucca* v_2 where M_1 and M_2 are positions

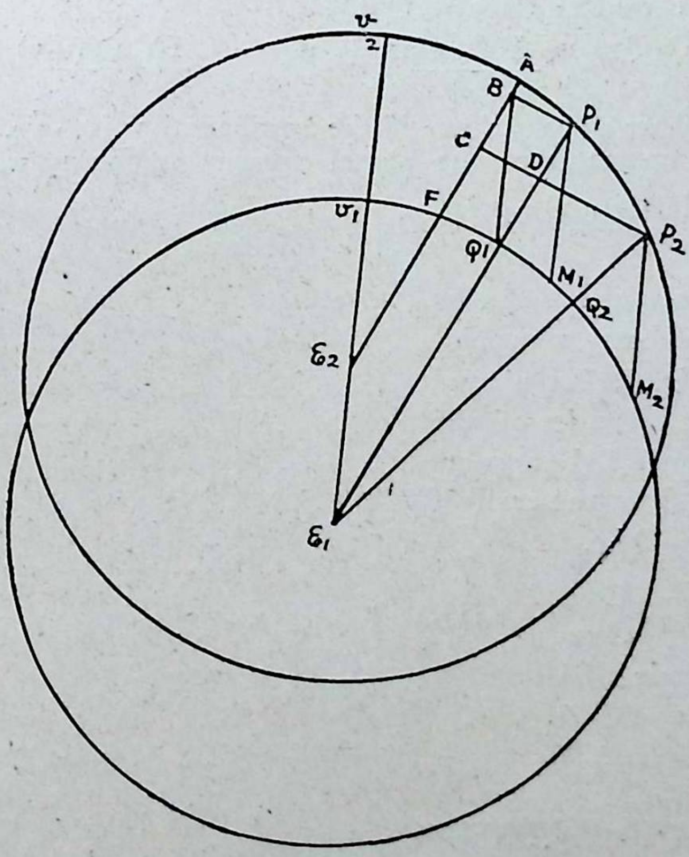

Fig 6.

of the mean planet in the Kakṣāmaṇḍala. The phrase "with respect to the Ucca" implies that the arc joining the corresponding true positions Q_1 and Q_2 does not give us the true motion of the planet but the motion in the true anomaly alone *i.e.* Spaṣṭa Kendragati, as is rightly remarked by Bhāskara. It is sought to compute Q_1, Q_2. Now lay out equal arcs P_1 A and Q_1F along the circles equal to the Śīghraphala θ so that ε_1 P 11 ε_2A. From P_1, P_2 drop perpendiculars on ε_2A namely P_1 B, P_2C. Their difference P_2D will be found first. By construction P_1 B and P_2 C are the H sines of the arcs P_1A, P_2A. Looking upon $P_1 P_2$ as an increment in the arc AP_1, P_2D will be the corresponding increment in the HSine. But Ap_1 being the śīghraphala, and P_1P_2 the motion in the mean anomaly ∂m, the jyāntara $P_2D = \text{HSin}(\theta + \partial m) - \text{H Sin}\theta = \dfrac{\text{HCos}\theta\partial m}{R}$ by Bhāskara's theory of Jyākhaṇḍa Sphuṭīkaraṇa or his differential formula that $\partial(\text{HSin}\theta) = \dfrac{\text{HCos}\theta\partial\theta}{R}$ (Ref. *A Critical study of Ancient Hindu Astronomy* of the author, page 10). From this value of P_2 D, the value of $Q_1 Q_2$ is got by looking upon $\varepsilon_1 P_2 D_1$ and $\varepsilon_1 Q_2 Q_1$ as similar triangles. This is not unrigorous as Bhāskara is talking of tātkalikagati ultimately when he is speaking of Jyā-Khaṇḍa-Sphutīkaraṇa, though he primarily used the words adyatana and śvastana to begin with. Hence $Q_1 Q_2 = \dfrac{\text{HCos}\theta\partial m}{R} \times \dfrac{R}{K} = \dfrac{\text{HCos}\theta\partial m}{K}$. Now Śīghrocca-Graha= Śīghrakendra. Taking the differentials, Śīghragati-grahagati=Kendragati which may be written u-v=Kendragati=Q_1Q_2

$$\therefore v = u - Q_1Q_2 = u - \frac{\text{HCcs}\theta\partial m}{K} = u - \frac{\text{HCos}\theta(u-v)}{K}$$

Now Bhāskara says that if the grahagati v is -ve, the planet is retrograde. This means that the planet appears stationary when

$$u - \frac{\text{HCos}\theta(u-v)}{K} = o \text{ i.e. } u = \frac{\text{VHCos}\theta}{\text{HCos}\theta - K}. \qquad (a')$$

The truth of this statement can be seen from the modern viewpoint as follows from fig. 7. Let u' and v' be the linear velocities of the Earth and the planet J. J appears stationary as seen from the earth if $u' \text{Cos}\,\varepsilon + v'\text{Cos}\theta = O$ i.e.

when $\dfrac{u'}{v'} = -\dfrac{\text{Cos}\theta}{\text{Cos}\varepsilon}$ (1).

But from the triangle SEJ $R\text{Cos}\theta + a\text{Cos}\varepsilon = K$ (2).
Eliminating Cosε
from (1) and (2) $\dfrac{u'}{v'} = -\dfrac{a\text{Cos}\theta}{K - R\text{Cos}\theta}$

But $u' = au$, $v' = Rv$ where u and v' are the angular velocities

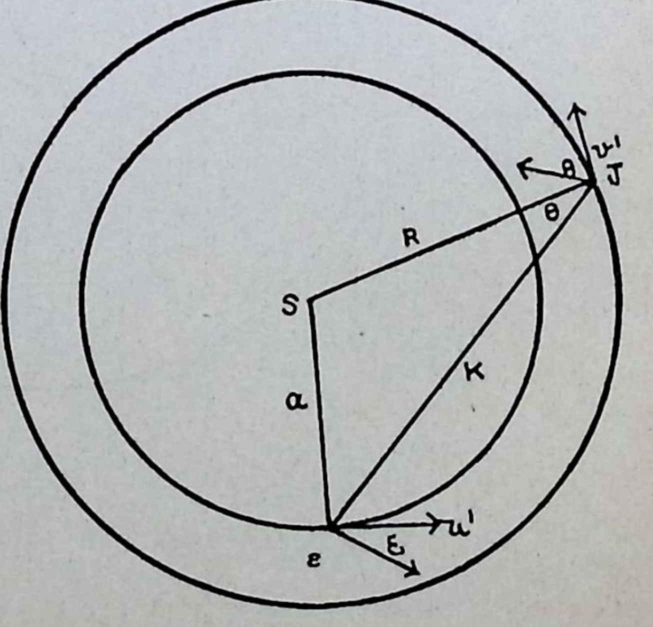

Fig 7.

of the earth and the planet or what is the same the Sun and the planet i.e., the Śīghra and the planet $\therefore \frac{au}{Rv} = \frac{a\cos\theta}{R\cos\theta - K} \therefore u = \frac{vH\cos\theta}{H\cos\theta - K}$ as given by Bhāskara above in (a')

There are other mathematical facts also, for example (1) the method of successive approximations used by Hindu Astronomers (2). The udayāntara correction (3) The rationale of repeated use of the Śīghra and Mandaphlalas etc. which deserve elucidation.

SOME IMPORTANT MATHEMATICAL METHODS AS CONCEIVED IN ANCIENT INDIA

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In ancient India, secular knowledge was considered to be a helpful adjunct to spiritual knowledge. The six Vedāṅgas (limbs of the Vedas) were meant for the primary object of helping the study of the Vedas. Thus the sciences of geometry and astronomy grew, in the early days, as help to the religious needs in the construction of the Vedic altars and in the performance of the Vedic sacrifices.

The fact that mathematics was not studied for its own sake resulted in the paucity of treatises devoted wholly to that subject . For the same reason the aim of early Indians was not to build up an edifice of logically deductive science of mathematics on the foundation of a few self-evident fundamental axioms. Even a visual demonstration, or a non-rigorous derivation and explanation was quite an accepted form of the proof. Of course, there must have been some approaches and ways through which the indigenous mathematical rules were discovered, invented, or arrived at.

The simplest and the most important Indian mathematical method found in Sanskrit works is the Rule of Three or *Trairāśika* which was highly appreciated by the Indians because of its universal application to ordinary problems. The famous Bhāskara II (twelfth century A.D.) eulogises the Rule of Three in the following words[1]

त्रैराशिकेनैव यदेतदुक्तं व्याप्तं स्वभेदैर्हरिणेव विश्वम् ।

(*Līlāvatī, Chāyā-Vyavahāra*)

'As the Lord Hari pervades the universe with His manifestations so does the Rule of Three, with its variations, pervade the whole science of calculation enunciated upto now.'

He further remarks—[2]

यत्किंचिद्गुणभागहारविधिना बीजेऽत्र वा गण्यते
तत्त्रैराशिकमेव निर्मलधियामेवावगम्यं विदाम् ।

(*Līlāvatī, Chāyā-Vyavahāra*)

'Whatever is computed, whether in algebra or in arithmetic by means of multiplication or division, may be comprehended by the sagacious learned as the Rule of Three.'

Similarly Nīlakaṇṭha Somasutvan (c. 1500 A.D.) in his *Āryabhaṭīya Bhāṣya* (hereafter referred as NAB) says[2]:

भुजाकोटिकर्णन्यायेन त्रैराशिकन्यायेन चोभाभ्यां सकलं ग्रहगणितं व्याप्तम् ।

'By both the Bhujā-koṭi-karṇa Nyāya (the so-called Pythagoras Theorem) and the Rule of Three the whole of planetary computation is pervaded.'

Now what is the Rule of Three? NAB (Part I, p. 34) quotes the verse

इच्छां फलेन संहत्य प्रमाणेन विभाजयेत् ।
इच्छाफलं भवेल्लब्धमेवं त्रैराशिकं मतम् ॥

'Multiply the requisition by the fruit and divide by the argument. The result is the produce. This is the Rule of Three.'

In other words, we may say that if the argument m yields (or corresponds to) the fruit f, then the requisition i will yield the desired produce P. That is,

$$P = i.f./m$$

The Rule of Three is found in the *Āryabhaṭīya* (see NAB part I, p. 153) of Āryabhaṭa I (born 476 A.D.) in the following words—

त्रैराशिकफलराशिं तमद्येच्छाराशिना हतं कृत्वा ।
लब्धं प्रमाणभजितं तस्मादिच्छाफलमिदं स्यात् ॥ २६ ॥

(*Āryabhaṭīya, Gaṇitapāda*).

The commentator adds—

इच्छाफलप्रमाणैस्त्रिभी राशिभिः साध्यं गणितं त्रैराशिकम् ।

That is, the calculation done with the three quantities—requisition, fruit, and argument is the Rule of Three.

The Rule of Three is a basic rule of Arithmetic. When used in the context of Geometry, it may very well be interpreted as the theorem which states the proportionality of the corresponding sides of similar plane polygonal figures. Similarly in connection with the interpolation theory, the Rule of Linear Interpolation or the Straight Line Law may be regarded as merely a simple application of the Rule of Three.

Examples of the Rule of Three from Arithmetic, that is, to the commercial and other problems of every-day life are frequently found, accompanying the statements of the rule, in the texts, commentaries and in modern histories of mathematics. Here we shall give examples related to the other fields and emphasise the importance of the Rule of Three.

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Let, for positive integral n,

$S_n = R \sin nh$
$D_1 = S_1 = R \sin h$
$D_{n+1} = S_{n+1} - S_n$
$C_n = R \cos nh$
$E_1 = C_1 = R \cosh$
$E_{n+1} = E_n - E_{n+1}$
It is easy to see that we have

$$D_{n+1} = R \cos (nh + h/2). \ (\text{crd}h)/R \qquad \ldots\ldots\ldots\ldots \qquad (1)$$

and

$$E_{n+1} = R \sin (nh + h/2). \ (\text{crd}h)/R \qquad \ldots\ldots\ldots\ldots \qquad (2)$$

R being the radius of the circle of reference (see the accompanying Figure No. 1).

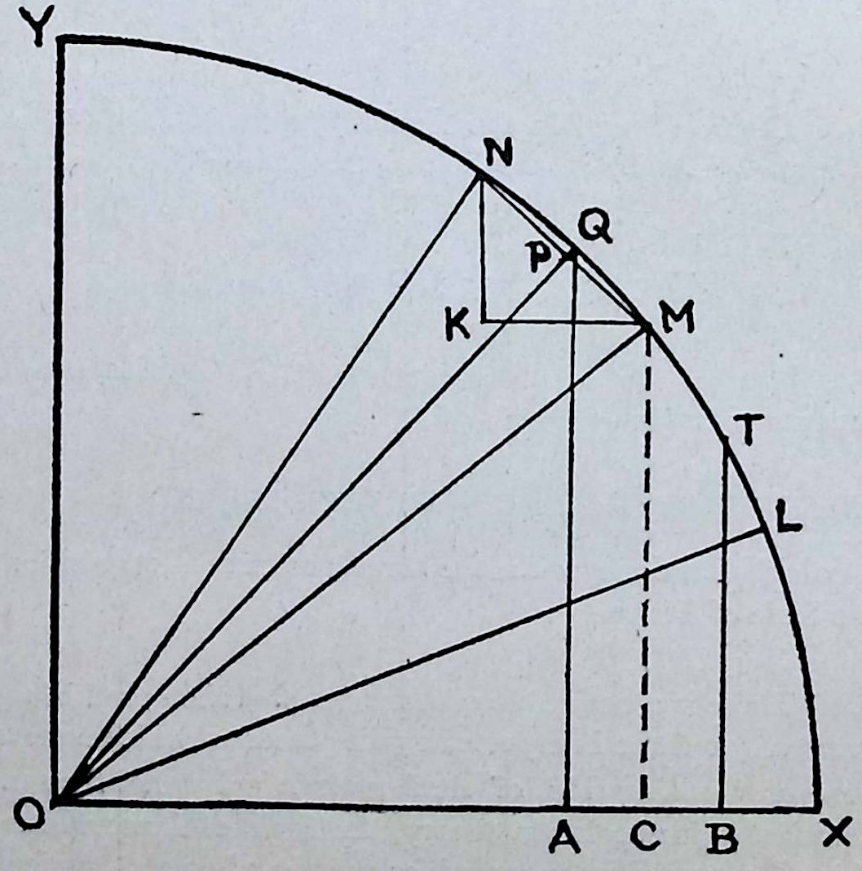

FIGURE No.1

where only a quadrant is shown.

The trigonometrical results (1) and (2) are easily proved trigonometrically, that is, by using some trigonometrical identities. But in NAB (part I, pp. 48-50), they have deen stated as two Rules of Three and proved geometrically by the proportionality of the sides of a set of similar right-angled triangles. The text quoted is

एकचापसमस्तज्या श्रुतिरूपाखिलेष्वपि ।
चापभागेष्विहेच्छा स्यान्मानं व्यासदलं तथा ॥
तत्तत्कार्मुकमध्याग्रे कोटिदोर्ज्ये फले उभे ।
इच्छाफले तु दोःकोट्योः खण्डज्ये ज्ञेयता ययोः ॥
त्रैराशिकद्वयं कार्यं चापे चापे तयोश्च तैः ।

'The chord of the (elemental) arc in the form of a hypotenuse is the requisition throughout. The radius is the argument in the same way. The Cosine and the Sine at the mid-point of the elemental arc are the two fruits. The two produces are the Sine and Cosine differences. These two Rules of Three should be applied from (elemental) arc to arc.'

Thus we have results equivalent to the trigonometrical formulas (1) and (2) but expressed in arithmetical language of the Rule of Three.

The geometrical proof given in the NAB, following the statement of the rules, is merely based on the proportionality of the sides of the triangles OAQ and NKM. For we have

$$NK/OA = KM/QA = NM/OQ$$

from which we get

$$NK = OA.\ NM/OQ$$

$$KM = QA.\ NM/OQ$$

which are equivalent to (1) and (2).

But the matter does not end here. The NAB (part I, pp. 50-52) now shows a piece of beautiful mathematics found in Sanskrit works by giving an ingenious proof of the well-known property that the second order differences of sines are proportional to the sines themselves. This we outline now. We have

$$D_{n+1} = OA.\ (\text{crd } h)/R$$

and

$$D_n = OB.\ (\text{crd } h)/R$$

Therefore,

$$D_n - D_{n+1} = (OB-OA).\ (\text{crd } h)/R$$

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But by (2) applied to the elemental arc TQ

$$OB - OA = (\text{Sine at middle of TQ}).\ (\text{crd } h)/R$$
$$= MC.\ (\text{crd } h)/E$$
$$= (Sn).\ (\text{crd } h)/R$$

Hence the above becomes

$$D_n - D_{n+1} = (Sn).\ (\text{crd } h)^2/R^2$$

In this crd h and R are same for all elemental arcs. So the NAB (part I, p. 52) rightly concludes that

भुजाज्यानुसारिण्येव ज्याखण्डानां वृद्धिः ।

'The (numerical) increase in the Sine-difference is proportional to the Sines themselves.'

$$D_n - D_{n+1} = (D_1 - D_2).\ S_n / S_1$$

Rules equivalent to this are found in the *Āryabhaṭīya*, (see NAB, p. 45) and many subsequent Indian works. After commenting on the rule the NAB (part I, p. 45) says.

एतदेव त्रैराशिकं सूर्यसिद्धान्तेऽपि......

'The same Rule of Three is found in the *Sūrya Siddhānta* also' and quotes the full rule from the latter work.

Now we shall give some astronomical illustrations of the Rule of Three. For finding the declination when the longitude of the body is , the Indian rule is[4]

$$R \sin \delta = (R \sin \omega).\ (R \sin \lambda)/R$$

The commentator Govinda Svāmin (c. 800-850) gives the following Rule of Three for the above[5]:

यदि विषुवदपक्रमसंपातात् त्रिभज्यया विषुवतोऽपायनं
चतुर्विंशतिभागज्या लभ्यते, तदेष्टज्यया किमिति ।

'If we get Sine of 24 degrees(that is, R sin w) as the declinational Sine when the Sine of the longitude, measured from the point of intersection of the equator and ecliptic, is equal to the radius, then how much shall we get from a given Sine of longitude?'

Thus we get the above rule.

Similarly, the same commentator gives an Indian proof of the formula for right ascension (Laṅkodaya) by using two Rules of Three which may be outlined as follows.[6]

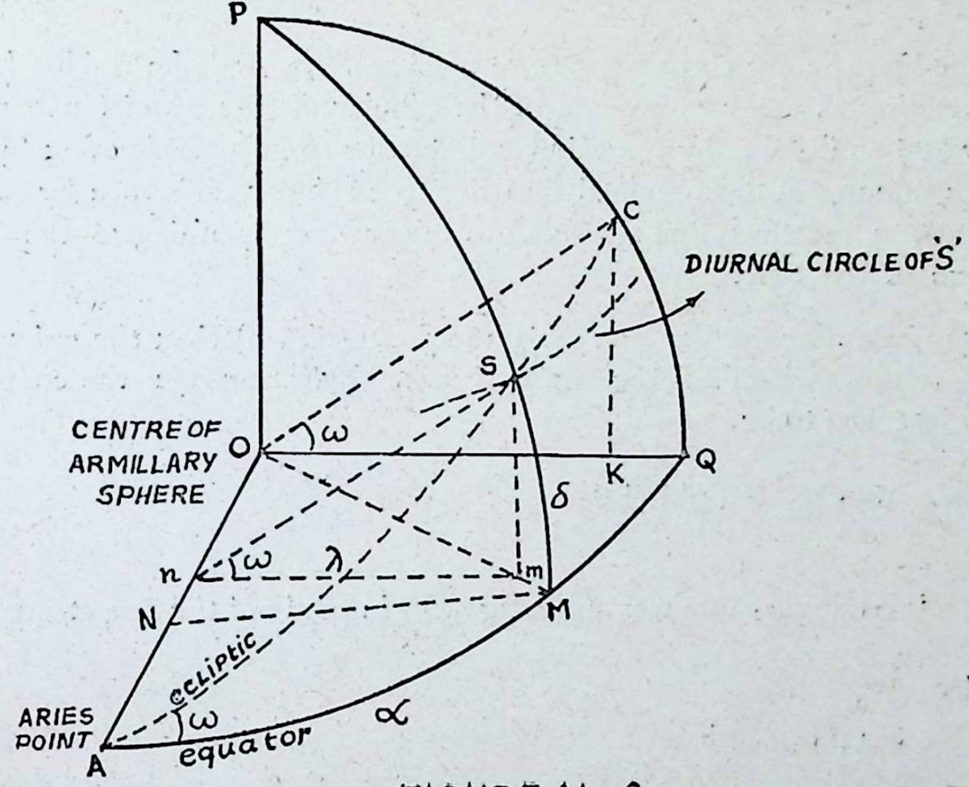

FIGURE No. 2

From the similar triangles mnS and KOC (see Fig. No. 2) we have

$mn/nS = OK/OC$

or, $mn = (R \sin \lambda) . (R \cos\omega)/R$

Also from the similar triangles MNO and mnO we get

$MN/mn = OM/Om$

giving

$MN = (mn) . R/R \cos \delta$

Hence, by above

$MN (= R \sin \partial) = (R \sin\lambda) . (R \cos \omega)/R \cos \delta$

By using spherical trigonometry (sine-cosine rule for the triangle SAM) the above can be written directly.

Another important Indian mathematical method used by Sanskrit writers is that of successive approximation, that is the Process of Iteration (Asakṛt-karma). This procedure was adopted generally for achieving higher accuracy particularly when exact methods were rather complicated or unknown. For example, Brahmagupta gives in his *Khaṇḍa-khādyaka* (c. 665 A.D.) a rule for finding the arc or angle, when its sine is known, by using the method of iteration. The basic text is[7*]—

चापानयने नवशतविकलवधाद् भोग्यलब्धलिप्ताभिः ।
कृत्वा खण्डकमसकृत् तल्लब्धकला विकलचापम् ॥

Khaṇḍakhādyaka IX-14.

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P. C. Sengupta translates Brahmagupta's Rule as follows[8]:

"In finding the arc corresponding to a given Sine, find the residue left after substracting as many as possible of the tabular differences of Sines, multiply it by 900 and divide by the tabular difference to be passed over; by means of the minutes of are obtained find the true tabular difference by repeating the process and thus find the minutes of arc corresponding to the required residue of the Sine."

If the given Sine lies between Sin ph and Sin (ph+h) then the unknown arc X will be $(ph+\theta)$ where θ is the residual arc. By linear rule the crude value of θ may be taken to be

$$\theta_o = (\text{Sin X—Sin ph}).\ h/D_{p+1}.$$

Now θ_o is crude because we are using D_{p+1} instead of the exact quantity T defined by

$$\text{Sin X}=\text{Sin ph}+T.\theta/h,$$

that is,

$$\theta=(\text{Sin X—Sin ph}).\ h/T.$$

But T itself is not known here. For a good approximation to T we may use Brahmagupta's another rule found in the same work and which gives the following expression of the bhogya-khaṇḍa[9]—

$$D_t = (D_p+D_{p+1})/2—(D_p—D_{p+1}).\ \theta/2h$$

We use this, with θ_o for θ, to get the first better approximation T_1 for T That is, we take

$$T_1 = (D_t) \text{ when } \theta=\theta_o.$$

Hence a better approximation of the residual are will be given by

$$\theta_1=(\text{Sin X—Sin ph}).\ h/T_1$$

Bhāskara II, in his *Siddhānta Śiromaṇi* (Graha Gaṇita II,17), gives a rule which yields θ_1 for the arc. However, he adds that "the result is somewhat not accurate (but) should be accepted because it is easily obtained. Otherwise the true value can be found out either by an algebraic process or by iteration method".

With θ_1 we can now find the second better approximation T_2 for T given by

$$T_2=(D\ ) \text{ when } \theta=\ \theta_1$$

and then use T_2 to get a still better approximation to the residual arc by

$$\theta_2=(\text{Sin X—Sin ph}).\ h/T_2$$

and so on.

The process of Iteration* can very nicely explain the approximation[10]

$$\sqrt{2} = 1 + (1/3) + (1/3.4) - (1/3.4.34)$$

found in the *Śulba Sūtras*, and the rule[11]

$$\sqrt{a^2 + x} = a + (x/2a) - (x/2a)^2/2\ \{\ (a + x/2a)\ \}$$

which is found in the Bakshāli Manuscript. When x is small in comparison with a we have, crudely,

$$(a^2 + x)^{\frac{1}{2}} = a$$

For a better approximation we assume

$$(a^2 + x)^{\frac{1}{2}} = a + c_1$$

where c_1 is the correction term. Squaring and neglecting the square of c_1, we get

$$(a^2 + x)^{\frac{1}{2}} = a + (x/2a) \qquad \ldots\ldots\ldots \qquad (A)$$

as the two term-approximation. For still better approximation we assume

$$(a^2 + x)^{\frac{1}{2}} = a + (x/2a) \pm c_2$$

and repeat the above process. The required rule will then be obtained.

It should be noted that by the so-called Binomial Theorem Expansion we can get (A) but not the third term of the Bakshāli Rule. The Linear Interpolation Method or the Rule of Three will give

$$(a^2 + x)^{\frac{1}{2}} = a + x/(2a + 1)$$

instead of (A). As a numerical example of this Rule of Three we have

$$\sqrt{10} = (3^2 + 1)^{\frac{1}{2}} = 3 + 1/(4^2 - 3^2) = 22/7$$

Thus (with a and x each equal to one)

$$\sqrt{2} = 1 + (1/3)$$

is the first approximation got by the Linear process or the Rule of Three. For better approximation we assume

$$\sqrt{2} = 1 + (1/3) + e_1$$

Proceeding as before we get e_1. Then the required Śulba value can be obtained by repeating the process for getting the second correction. Starting with the linear approximation

$$\sqrt{3} = \sqrt{1 + 2} = 1 + (2/3)$$

and applying the above procedure we get[12]

$$\sqrt{3} = 1 + (2/3) + (1/3.5) - (1/3.5.52).$$

Lastly in this paper we present the process of averaging which has been found in the Sanskrit works. This mathematical method was applied for quick practical results particularly in connection with the problems of mensuration of areas and volumes. This method enabled the computation of approximate volume of irregular solids and excavations.

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* The iteration process has been used in Indian astronomy also, e.g. in finding true distances of the sun and the moon (see *Mahā-Bhāskarīya*, IV, 9-12).

For finding the area of a triangle or a quadrilateral, Brahmagupta (628 A.D.) gives the rules[13]

स्थूलफलं त्रिचतुर्भुजबाहुप्रतिबाहुयोगदलघातः ।
भुजयोगार्धचतुष्टयभुजोनघातात्पदं सूक्ष्मम् ॥ २१ ॥

(*Brāhmasphuṭasiddhānta*, Gaṇitādhyāya)

'The product of halves of the sums of the opposite sides is the gross area of a triangle or quadrilateral....................'.

That is,

$$A=\frac{(a+c)}{2}\cdot\frac{(b+d)}{2}\text{ approximately.}$$

This rule is obviously based on taking the average of the opposite sides.

Brahmagupta also gives a rule for finding the volumes of frustum like solids as follows[14]:

मुखतलयुतिदलगणितं वेधगुणं व्यावहारिकं गणितम् ।
मुखतलगणितैक्यार्धं वेधगुणं स्याद् गणितमौत्रम् ॥ ४५ ॥
औत्रगणिताद्विशोध्य व्यवहारफलं भजेत् त्रिभिः शेषम् ।
लब्धं व्यवहारफले प्रक्षिप्य भवति फलं सूक्ष्मम् ॥ ४६ ॥

(*Brāhmasphuṭa Siddhānta*, Gaṇitādhyāya)

Thus, according to the rule we have:

P=Practical volume to be equal to the area found by taking the mean of the linear dimensions of the top and bottom, multiplied by the height.

and

G=Gross volume to be equal to the mean of the areas of the top and bottom multiplied by the height.

Then the accurate volume V will be given by

$$V=P+(G+P)/3$$
$$=(2P+G)/3$$

In the case of a solid whose top and bottom are rectangles and h is the uniform height of the solid, we have

$$P=\frac{(a+á)}{2}\,\frac{(b+b')}{2}\times h$$

According to Datta[15], the equivalent of this formula seems to be used by the authors of the *Sulba Sūtras*. Also

$$G=\frac{(ab+\grave{a}\,b')}{2}\times h$$

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By Brahmagupta's rule we easily get

$$V = \{ab + \acute{a}\,b' + (a + \acute{a})\ (b + b')\}.(h/6)$$

This is mathematically correct.

For frustum of a cone we will have

$$P = \pi \frac{(r_1 + r).^2}{?}\ h$$

and

$$G = \left(\frac{\pi r_1{}^2 + \pi r_2{}^2}{2}\right) h$$

And in this case also we get the mathematically correct volume.

An elegant generalisation of the rule of Brahmagupta, which clearly reflects the typicalness of the method of averaging, is given by Mahāvīra (c. 850 A.D.) in his *Gaṇita-sāra-saṅgraha* VII, 9—12, as follows[16]:

बाह्याभ्यन्तरसंस्थिततत्तत्क्षेत्रस्थबाहुकोटिभुवः ।
स्वप्रतिबाहुसमेता भक्तास्तत्क्षेत्रगणनयान्योन्यम् ॥ ९ ॥
गुणिताश्च वेधगुणिताः कर्मान्तिकसंज्ञगणितं स्यात् ।
तद्बाह्यान्तरसंस्थिततत्तत्क्षेत्रे फलं समानीय ॥ १० ॥
संयोज्य संख्याप्तं क्षेत्राणां वेधगुणितं च ।
औण्ड्रफलं तत्फलयोर्विशेषकस्य त्रिभागेन ॥ ११ ॥
संयुक्तं कर्मान्तिकफलमेव हि भवति सूक्ष्मफलम् ।
.. ..

M. Rangacharya translates the passage thus[17]:

'The values of the base and the other sides of the figure representing the top sectional area are added respectively to the value of the base and corresponding sides of the figure representing the bottom sectional area. The (several) sums (as arrived at) are divided by the number of the sectional areas taken into consideration (in the problem). The resulting quantities are multiplied with each other (as required by the rules bearing upon the finding out of areas when values of the sides are known). The area (so arrived at), when multiplied by the depth, gives rise to the cubical measure designated the *Karmāntika* result. In the case of those same figures representing the top sectional area and the bottom sectional area, the value of the area of (each of)these figures is (separately) arrived at. The area values (so obtained) are added together and then divided by the number of (sectional) areas (taken into consideration). The question (as obtained) is multiplied by the value of the depth. This gives rise to (the cubical measure designated) the *Auṇḍra* result. If one-third of the difference between these two results is added to the *Karmāntika* result, it indeed becomes the accurate value (of the required cubical contents)."

Let the number of sections considered be n and f (a, b, c,......) denote the area of the section when its linear dimensions are a, b, c,..........Let $a_1, b_1, c_1,\ldots\ldots\ldots;\ a_2,\ b_2,\ c_2.\ \ldots\ldots\ldots\ldots;\ a_n,\ b_n,\ c_n,$ ....be the linear dimensions of the sections considered. Then, according to Mahāvīra's Rule, we have

Karmāntika Volume, K say

$$=h.f.\ \{a_1+a_2+\ldots\ldots\ldots\ldots+a_n)/n,\ \ (b_1+b_2+\ldots\ldots+b_n)/n,\ldots.\}$$

and Auṇḍra volume, N say

$$=h.\ \{\ f\ (a_1,\ b_1,\ldots\ldots)+f(a_2,\ b_2,\ldots\ldots)+\ldots\ldots\ldots\ldots +f\ (a_n,\ b_n,\ \ldots\ldots\ldots)\ )/n.$$

Then the accurate volume will be given by, like Brahmagupta's Rule,

$$V=K+(N\ +\ K)/3$$
$$=(2K+N)/3.$$

Mahāvīra himself gives examples when the sections are squares, rectangles, circles and triangles and considers examples upto 3 sections. A typical example is

नवतिरशीतिः सप्ततिरायामश्चोर्ध्वमध्यमूलेषु ।
विस्तारो द्वित्रिंशत् षोडश दश सप्तवेधोऽयम् ॥

Here, lengths and breadths of the three rectangular sections are 90, 80, 70 and 32, 16, 10 respectively and depth is 7. So that

$$K\ =\ \frac{(90+80+70)}{3}.\ \frac{(32+16+10)}{3}\ .\ 7$$

$$N\ =\ \frac{(90\times32+80\times16+70\times10)}{3}.\ \ 7.$$

It should be noted that sections are not similar rectangles.

Bhāskara II (c. 1130) gives a rule for finding the equivalent average sectional area (samam kṣetraphalam) as follows[18] :

मुखजतलजतद्युतिजक्षेत्रफलैक्यं हृतं षड्भिः ।
क्षेत्रफलं सममेवम् .... ॥

Līlāvatī, Khātavyavahāra

" The aggregate of the areas at the top and at the bottom,and of that resulting from the sum (of the sides of the summit and base),being divided by six, the quotient is the mean area........"

That is, let a, b,........and á, b′,........be the linear dimensions of the top and base, and A_1, A_2, A_3 be the areas of the top, base and of that which is obtained by summing the respective linear dimensions of the top and base, so that

$$A_1\ =\ f\ \ (a,\ \ b,\ \ \ldots\ldots\ldots\ldots\ldots)$$
$$A_2\ =\ f\ \ (\acute{a},\ \ b,'\ \ \ldots\ldots\ldots\ldots\ldots)$$

and

$$A_3\ =\ f\ \ (a\ +\ \acute{a}),\ \ (b+b'),\ldots\ldots\ldots\ldots\ldots)$$

Then according to the above rule the mean (or effctive) area A will be given by

$$A\ =\ (A_1+A_2+A_3)/6.$$

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It may be easily seen that this rule is a refined form of Brahmagupta's method, since

$$h.\ (A_1+A_2)/2 = G$$

and

$$h.\ A_3/4 = P.$$

Finally, Bhāskara II may be quoted again for giving a rule which is strictly based on the process of averaging when the length, breadth and depth vary from place to place. He says[19] :

> गणयित्वा विस्तारं बहुषु स्थानेषु तद्युतिर्भाज्या ।
> स्थानकमित्या सममितिरेवं दैर्घ्ये च वेधे च ॥ (लीलावती, खातव्य०)

> " Taking the breadth in several places, let the sum of the measures be divided by the number of places, the quotient is the mean measure. So likewise with the length and depth."

Thus when any dimension varies from place to place we are advised to take the mean or average of measures at several places. The commentator Gaṇeśa, while commenting on the above observes[20]:

> यथा यथा बहुषु स्थानेषु विस्तरादिकं गण्यते तथा तथा सममितिः सूक्ष्मसूक्ष्मतरा स्यात् ।

That is, the mean measure becomes more and more accurate when computed from measures taken from more and more places which is a general principle for making the average representative of the mass.

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SANSKRIT AND MATHEMATICS

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While writing this short paper, I am aware of the charge levelled against us by some Western scholars like Mr. W.W. Rouse Ball that we Hindus pretend and believe that we are the most ancient people on the face of the earth and that to us all sciences own theirs creation[1]. But I am happy to see that there is a school of thinkers like Messrs Lancelot Hogben[2], Laplace, Dantzing[2a], David E. Smith[2b] and some others who hold views otherwise and accept the originality and invention of some principles of mathematics known to the present generation attributed to the Hindus.

I fully concur with Mr. Hogben[3] when he says that mathematics is the mirror of civilization. If with that aspect in view we look at the mathematics given by the Sanskrit authors we find that India was one of the foremost civilized countries in the world which has richly contributed to the knowledge of the science in the world[4].

If we start with the Dictionary of mathematical terms known to India, we find that our Dictionary gives a number of words for counting beyond 'million'. For the number words, the Westerners halt at million and for further counting they have to count in only millions, *viz.*, ten millions,hundred millions etc. After million (prayuta) we have Koṭi, Arbuda, Abja, Kharva, Nikharva, Mahāpadma, Śaṅku,Jaladhi, Antya, Madhya, Parārdha for counting ten times the multiples of millions to the degree of infinity (*Yajurveda Samhitā* 17.2)[5]. Thus, Dictionary known to India even today is unknown to the West. On this count alone our claim of having an advanced civilization in the past stands on solid grounds.

I shall not indulge in a controversy whether Algebra was originated in India, or whether Calculus has its origin in the soil of this country, or whether Geometry and Trigonometry were known to the ancient people in India. But before proceeding further I will have to assert that zero and its implication were known to India. It was the Indians who first said in the Veda, Vedānta, and also in mathematics that the value of zero is not nil but zero stands as an emblem of infinity[6].

As held out by Vinay Kumar Sarkar, π was known to Vedic people[7]. I shall quote Thibaut in regard to our claim of Geometry: "Thes Śulba Sūtras, as we have stated before, come from the eighth century before Christ. The geometrical theorem that the square of the hypotenuse is equal to the square of the other two sides of a rectangular triangle is ascribed by the Greeks to Pythagoras, but it was known to India centuries before and Pythagoras undoubtedly learned this rule from India".[8]

It must be remembered that in India Mathematics was an ingredient of the science of Jyotiṣa which was a Vedāṅga-an organ of Vedas useful to indicate the appropriate time for the performance of the Yajnas. The *Nārada Purāṇa*, one of the eighteen principal Purāṇas in India, deals at length with the discussion of the Vedāṅgas and it thus also deals with mathematics. In the *Nārada Purāṇa* we find some surprising methods with the help of which a mathematician would say the quantity of foodgrains seeing a heap of the same , the quantity of water in a lake, or the weight of stones in a hill, or the weight of a piece of iron on seeing them by mathematical calculations.

According to the *Nārada Purāṇa*, if the length, breadth and depth (in Aṅgulas) of a reservoir are multiplied, the result would be the quantity (weight) of water in the reservoir in *Droṇas*. Similarly, to find out the weight of foodgrains in a heap, the length, breadth, and height of the heap (in Aṅgulas) multiplied and divided by 96 would give the weight of the foodgrains (in Droṇas) in the heap of foodgrains. The length, breadth and thickness of a piece of stone (in Aṅgulas) multiplied, and then divided by 1150 would give the weight of the piece of stone in Droṇas. Similarly, the length, breadth and thickness of a piece of iron (in Aṅgulas) multiplied and divided by 585 would give the weight of the piece of iron in Droṇas. These rules remain to be verified by tests.[9]

If we turn to Ārya Bhaṭa (5th century A.D.),we find that not only the decimals were known in India in his days,but Ārya Bhaṭa could give a shorthand method of narrating decimals in algebraical form. According to him every letter of the alphabet from *ka* to *ma* and vowels can be used to denote numbers in decimals[10]. He said in unambiguous terms that formation of days and nights was due to the movement of the earth and not that of the sun as believed by many.

Thus the contribution of India to the science of mathematics is from ancient times and considerably rich.

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BRAHMAGUPTA'S WORKS AND THEIR INFLUENCE IN AND OUTSIDE INDIA

R.N. RAI

Brahmagupta, born in A.D. 598, was one of the greatest Indian astronomers. He wrote three books: the *Dhyānagrahopadeśa*, the *Brāhmasphuṭasiddhānta* which he wrote at the age of 30 and the *Khaṇḍakhādyaka* which he wrote when he was 67 years old. The third book gives simplified methods to obtain results according to the astronomical constants of his great predecessor, Āryabhaṭa I, though earlier, in his second book, he had severely criticised him along with other previous astronomers. The second is his main book. The first is the *Karaṇagrantha* like *Khaṇḍakhādyaka* but based on the contents of *Brāhmasphuṭasiddhānta*.

It is known that the second and third books were commented upon by Balabhadra and Caturbeda Pṛthūdaka Svāmi. Manuscripts of the commentaries of Balabhadra are not now available. But Pṛthūdaka Svāmi in his commentary on *Brāhmasphuṭasiddhānta* quotes from Balabhadra's commentary on *Brāhmasphuṭasiddhānta*[1] and al-Birūnī seems to be familiar with both the commentaries[2]. The third book is known to have been commented upon by Lalla, Bhaṭṭotpala, Someśvara, Varuṇa, Āmarāja and Śrīdatta.

Brahmagupta was not only a great astronomer but also a great mathematician and has made original contributions to both algebra and geometry. Among other results in algebra he has stated, without proof, the result that[3]

$$\frac{a}{b} = \frac{a}{b+h} + \left(\frac{a}{b+h}\right)\frac{h}{b}.$$

gives a convenient method for evaluating a/b.

But his most important contribution to algebra is the solution of the indeterminate equation

$$Nx^2 + c = y^2$$

He stated that if for two convenient values k and k′ of C, the solutions are (α, β) and (α', β'), then

$$X = \alpha\beta' \pm B\alpha' \text{ and } Y = \beta\beta' \pm N\alpha\alpha'$$

are two other pairs of the solutions of equation[4]

$$Nx^2 + kk' = y^2$$

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This result can be easily proved. Brahmagupta had indicated how to obtain solutions of the equation $Hx^2 \times 1 = y^2$, if solutions of the equation $Nx^2 + C = y^2$ for $C = -1$, ± 2, and ± 4 are known. These results were later utilised by Bhāskara II (A.D. 1150) to develop his *cakravāla* method to obtain solutions of the equation

$$Nx^2 + 1 = y^2$$

As has been observed by Srinivāsiengar it is therefore fitting that this equation be called Brahmagupta-Bhāskara equation[5].

Brahmagupta made a deep study of right-angled triangles and stated that a, b, c form a right-angled triangle, if

$$a = 2mn,\ b = m^2 - n^2,\ \text{and}\ c = m^2 + n^2$$

where m and n are any two rational numbers[6].

He also gave a rule for constructing right-angled triangles starting from a given side[7]. He says: "The given side, the square of the given side dividing by any desired number and the result reduced by the same number and the difference halved, form the adjacent sides of a rectangle of which the diagonal is equal to half the difference increased by that very desired number." This means that

a, $\frac{1}{2}\left(\frac{a^2}{m} - m\right)$, are the sides and the diagonal is equal to $\frac{1}{2}\left(\frac{a^2}{m} + m\right)$

If we now take two numbers m and n and form the two sets of numbers $a,\ \frac{1}{2}\left(\frac{a^2}{m} - m\right),\ \frac{1}{2}\left(\frac{a^2}{m} + m\right)$ and $a,\ \frac{1}{2}\left(\frac{a^2}{n} - n\right),\ \frac{1}{2}\left(\frac{a^2}{n} + n\right)$, both sets will give right-angled triangles. If we now put the triangles side by side with 'a' common and the two right angles adjacent, we will get a triangle of altitude *a* and the sides $\frac{1}{2}\left(\frac{a^2}{m} + m\right)$, $\frac{1}{2}\left(\frac{a^2}{n} + n\right)$ and $\frac{1}{2}\left(\frac{a^2}{m} + \frac{a^2}{n} - m - n\right)$ in which the sides and the altitude are rational numbers[8].

He states the following formulae for the area of a triangle and that of a quadrilateral[9]:

$$\text{Area of triangle} = \sqrt{s(s-a)(s-b)(s-c)},$$

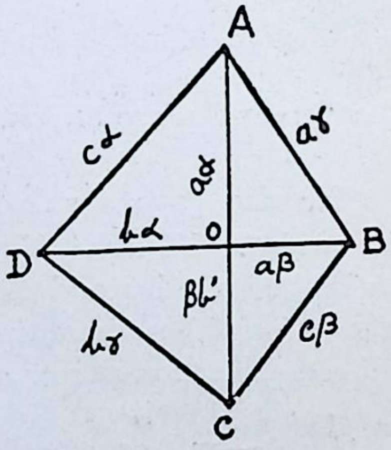
$$\text{Area of quadrilateral} = \sqrt{(s-a)(s-b)(s-c)(s-d)},$$

where s is half the sum of the sides. Here he seems to be considering only cyclic quadrilaterals.

Another result stated by Brahmagupta is that the diameter of the circumcircle of a triangle is $\frac{bc}{p}$ where b and c are two sides of the triangle and p is the perpendicular from their point of intersection on the third side[10]. Brahmagupta has not proved this result but it can be easily proved.

This result he has utilised in constructing two types of cyclic quadrilaterals with rational sides[11]. Let us take two sets of numbers (a,b,c) and $(\alpha,\beta,\gamma,)$ such that $a^2+b^2 = c^2$ and $\alpha^2 + \beta^2 = \gamma^2$

These sets can easily be obtained by the method previously described. Now we can construct triangles OAB, OBC, OCD, ODA with the sides as shown. Then the radius of the circumstcircles of the triangle BCD is $\frac{1}{2}\frac{c\beta.b\gamma}{b\beta} = \frac{1}{2}c\gamma$. But this is also the radius of the circumcircle of triangle BDA. Hence the circle passing through the points, B,C and D will also pass through A and we get a cyclic quadrilateral. In this case the two diagonals are at right angles to each other. If we now construct another quadrilateral with one of the diagonals equal to $c\gamma$ composed of triangles with sides $(a\gamma,b\gamma,c\gamma,)$ and $(c\alpha,c\beta,c\gamma,)$ the quadrilateral consists of two right-angled triangles and it is easy to see that this also is cyclic. They are known as Brahmagupta's quadrilaterals. They have both the same area which is equal to



$$\frac{1}{2}(ab\gamma^2 + \gamma\beta C^2).$$

Another result stated by Brahmagupta, which is true for cyclic quadrilaterals is the following[12]—

The sum of the products of the two pairs of sides about any diagonal divided by the sum of the products of the pairs of sides about the other diagonal and the result multiplied by the sum of the products of the opposite sides gives the square of the first diagonal. Similarly for the second diagonal.

If the diagonal of length x has the sides (a,b) and (c, d) adjacent to it, and y is the length of the other diagonal, then,

$$x^2 = \frac{(ab+cd)\ (ac+bd)}{ad+bc}, \qquad y^2 = \frac{(ad+bc)\ (ac+bd)}{ab+cd}$$

He has also stated formulae for the construction of cyclic isosceles trapezium and a trapezium with three equal sides[13]. But the most important result is the formula for the second interpolation which he must have arrived at some time before A.D. 628 as according to him he wrote *Dhyānagrahopadeśādhyāya* before *Brāhmasphuṭasiddhānta* and the formula first occurs in *Dhyānagrahopdeśāanyāya*. This formula has been stated in connection with finding a more correct value of the *jyā* or *utkrāntajyā*. It says[14];

"Multiply the *vikalā* (remainder left over after subtracting as many complete area for which the results have been stated) by half the difference between the *Gatakhaṇḍa* (last *Khaṇḍajyā* etc. crossed over) and the *Bhogyakhaṇḍa*(*Khaṇḍajyā* etc. of the arc difference in which the angle lies) and divide the product by 900′. Add the result to half the sum of the *Gatakhaṇḍa* and *Bhogyakhaṇḍa*, if their half sum is less than the *Bhogyakhaṇḍa*; subtract if greater. The result in each case gives the correct tabular difference."

The direction to divide by 900′ is given because both in *Dhyānagrahopadeṣa* and *Khaṇḍakhādyaka*, the values of *Khaṇḍajyās* are given at intervals of 900. If the tabular differences are given at any other interval, that value should be taken. According to the above, the correct tabular difference is

$$\triangle f=\tfrac{1}{2}(\triangle_n f + \triangle_{n+1} f) \pm \tfrac{1}{2}(\triangle_n f \sim \triangle_{n+1} f) \frac{\theta}{h}$$

where the values of the function have been tabulated at intervals of h and the value is required at the point $(nh+\theta)$. Hence

$$f(nh+\theta)=f(nh) + \frac{\theta}{2h}(\triangle_n f+\triangle_{n+1} f) + \frac{\theta^2}{2h^2}(\triangle_n f\sim\triangle_{n+1} f).$$

This is the first instance of the use of second interpolation in history. Although in the context in which it is stated, it seems to apply to *jyā* and *utkramajyā* evaluations only, it can be applied to any function as has been made clear by the commentators.

Similarly many new results were given by Brahmagupta in astronomy which were adopted by later astronomers. Bhāskara I has given a method for determining the east-west line at any place. However this does not take into account the small change in the position of the sun on the eccliptic. This was pointed out by Brahmagupta[15]. His commentator Pṛthūadakasvāmi has supplied the details of the correct method intended by him. This method was later adopted by Ṣrīpati and Bhāskara II.

Brahmagupta also gave a more correct method of calculating the true longitude of the sun and moon. This is important especially at the time of a solar ecclipse[16]. This method was later adopted by Bhāskara II. Other results given by Brahmagupta and adopted by later astronomers are the corrections to the *Mandocca* and *Mandaparidhi* of Mars, the correction of *Lambana* in a solar ecclipse, the angle subtended at the earth by the shadow of the earth at the orbit of the moon and his method of calculating the conjunction of planets.

Brahmagupta's influence on later Indian astronomers has been very great. They not only adopted many of his results but were also influenced by his other ideas. Āryabhaṭa I had stated that the origin of the apparent daily motion of the sun and stars from east to west is the rotation of the earth on its axis from west to east. For this statement he was severely criticised by Brahmagupta. Later astronomers accepted Brahmagupta's view.

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Similarly although Āryabhaṭa had earlier stated that all the four *yugas* are of equal duration and a *kalpa* consists of 1008 *caturyugas*, all the later astronomers followed Brahmagupta in assuming that the duration of the four yugas was in the ratio 4:3:2:1 and that the *Kalpa* consists of 1000 caturyugas, although, to reconcile some of the results, the authors of the modern *Sūrya Siddhānta* and *Mahāsiddhānta* were forced to assume a time-gap between the creation of the world and the beginning of the planets. In this they may also have been influenced by the opinion expressed in the *purāṇas*. Brahmagupta himself seems to have been a great believer in the ideas propagated by the religious books and criticises the *Romaka Siddhānta* and Āryabhaṭa I for expressing opinions not in accordance with the ideas of these books[17]. Following the *Purāṇas* he also stated that half the age of Brahmā has already passed[18]. He even criticises the astronomers Varāhamihira, Śriṣeṇa, Āryabhaṭa I and Viṣṇucandra for believing that it is not Rāhu which causes the ecclipses but the shadows of the sun and the moon, because the views of these astronomers were not in accordance with the teachings of the *Vedas*, Smṛtis and *Saṃhitās* like the *Garga Saṃhitā*.

It has been already stated that Balabhadra wrote commentaries on both the *Brāhmasphuṭasiddhānta* and the *Khaṇḍakhādyaka*. He also seems to have written a *Siddhānta* based on the constants of Brahmagupta. This is proved by the quotations given by Pṛthūdaka in his commentary on the *Brāhmasphuṭasiddhānta*[20] and by Bhaṭṭotpala in his commentary on the *Bṛhatsaṃhitā*. Other astronomers who have written *Siddhāntas* based on the constants of Brahmagupta are Śrīpati (A.D. 1039) and Bhāskara II (A.D. 1150). The only difference is that Śrīpati gives the figure 54 for the number of revolutions of the apogee of the Saturn in the place of 41 given by Brahmagupta.

Also a large number of *Karaṇas* were composed by astronomers based on the constants of *Brāhmasphuṭasiddhānta*. One was written by Durlabha of Multan in Śaka 848. From the method which he uses in calculating the *ahargaṇa*, as described by al-Birūnī, it is clear that he is using the constants of Brahmagupta[22]. Unfortunately it has been lost and al-Birūnī does not give its name. Another was composed by Raja Bhojadava in Śaka 964. Its name is *Rājamṛgāṅka* and here Bhoja gives corrections to be applied to the mean places of the planets obtained by the constants of *Brāhmasphuṭasiddhānta*. One Raja Dāsabala of the family Vallabha composed another *Karaṇa* named *Karaṇakamalamārtaṇḍa* in Śaka 980. Here also the constants of Brahmagupta along with corrections of *Rājamṛgāṅka* have been used for calculating the mean places of the planets. Bhāskara II, in addition to the *Siddhāntaśiromaṇi*, composed *Karaṇakutūhala* in Śaka 1105 based on the constants of Brahmagupta and the corrections of *Rājamṛgāṅka*. *Mahādevasaraṇi* of Mahadeo (Śaka 1238) and *Khaṭakasiddhi* and *Candrārki* of Dinakara (Śaka 1500) and other *Karaṇas* based on the contents of Brahmagupta are known to exist. There must have been many more which might have lost.

About A.D. 770, the two books of Brahmagupta *viz.*, *Brāhmasphuṭasiddhānta* and *Khaṇḍakhādyaka* were translated into the Arabic by Yaqūb Ibn Tārīq and Alfazāri[23] with the help of a Brahman Gaṇaka, *i.e.*, astronomer who accompanied in A.D. 770 an embassy from Sindh to Baghdad. They were called by the Arabs as *Sindhind* and *al-Arkand*. Yaqūb Ibn Tārīq in his book Tarkīb Al-aflāk, *i.e.*, Composition of the spheres, speaks of four kinds of measures of time, *viz.*, the *saura māna*, the *sāvana māna*, the *cāndra māna* and the *nakṣatra māna*. Al-Birūnī had with him copies of the translations but was not satisfied by them and criticises Yaqūb Ibn Tārīq for not understanding the exact meaning of *ūnarātra*[24].

About half a century later the methods of *Sindhind* were used by al-Khwārizmī to construct his astronomical tables in which he takes 17th February, 3102 as the date of the flood. This shows unmistakable Hindu influence as it is well known that in Hindu astronomy this date is taken as the beginning of *Kaliyuga*.

Many other astronomers constructed *zijes* based on Hindu methods. Abu Mashar al-Balkhī (A.D. 787-A.D. 886), who also had studied the *Sindhind* and the Zij *al-Arkand*, in his book "Conjunction and Transits", has given the mean longitudes of the planets at the times of the mean conjunctions of Saturn and Jupiter since the epoch of 17th February, 3102 B.C. Al-Battāni, who generally bases his work on Ptolemy's *almagest*, uses a gnomon of 12 parts as used in Hindu astronomy. Al-Birūni in the beginning of the 11th century spent a number of years in travelling in India and acquired a good knowledge of Sanskrit. He claims to have translated the *Laghujātaka* of Varāhamihira. Other books translated by him are *Khaṇḍakhādyaka* and *Brāhmasphuṭasiddhānta* of Brahmagupta, *Yogasūtra* of Patañjali, *Sāṅkhyāśāstra*, *Karaṇatilaka* of Vijayānanda and *Paulīsasiddhānta*.

The tables of al-Khwārizmī were revised by the Spanish astronomer Masalama al-Majriti. The knowledge of Hindu astronomy thus travelled from the eastern part of the Muslim world to the western part. Recently Prof. Thorndike brought to light a Latin manuscript (M.S. Ashmole 191 II) in which astronomical computations have been made for the year A.D. 1428 for the geographical latitude of New Minister, England[26]. In this also the year of the flood is taken to be February 16, 3102 B.C. This is only one day away from the *Kaliyuga* era. In the calculations use is made, not of Ptolemy chords, but of Hindu methods using sine-functions taking R=150, which is the value taken in *Khaṇḍakhādyaka* and *Dhyānagrahopadeśa* by Brahmagupta. Thus the influence of Brahmagupta's works was felt even in far off England.

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A CRITICAL APPRAISAL OF SANSKRIT WORKS ON ASTRONOMY AND MATHEMATICS

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Source materials concerning mathematices and astronomy in ancient and medieval India comprise besides published Sanskrit texts some archaeological inscriptions, unpublished manuscripts of palm leaves, birch paper, research articles etc. A critical assessment of these works becomes very difficult because of the large number of manuscripts remaining unpublished, and many of them being unavailable and untraced, and possibly destroyed. What is necessary under the present circumstances is a close, unbiased and persistent study of the manuscript materials, both published and unpublished with assessment of the contents, the identifications of the authors in view of the existence of several authors having the same name and of their dates and relationship to the different schools to which they belonged and other relevant information. However an attempt, though incomplete, has been made here to discuss the subject on the basis of the materials gathered from different sources and then to determine the positive contribution made by the Indians to the knowledge of mathematics and astronomy.

I. *Survey of Source Materials.*

In the Vedic literature we meet with notable record of mathematical and astronomical knowledge in connection with fixing the auspicious time for the performance of sacrificial ceremonies and for construction of sacrificial altars of proper shape and size. The *Śulba* works which give methods and solutions of various problems of construction of altars are seven in number of which the Śulba of Baudhāyana, Āspastamba, Kātyayāna and Mānava now available are the main sources of our information. The *Vedāṅga Jyautiṣa* (c. 200 B.C.) in its three recensions, now extant, may be regarded as one of the main sources of Vedic astronomy and also of mathematics.

In the post-Vedic Period (c. 200 B.C. to 400 A.D.) the progress in this direction was somewhat arrested for no original contributions to the development of astronomy and mathematics in the strictest sense was made. Nevertheless, the knowledge was somewhat extended owing to foreign contacts. In the religious works of the Jainas such as: *Sūryaprajṅapti*, *Sthānāṅgasūtra*, *Bhagavctīsūtra*, *Tattvārthādhigamasūtra* of *Umāsvātī*, *Anuyogadvārasūtra*, *Kṣetrasamāsa*, there is a considerable material relating to the knowledge of mathematics and astronomy. A large body of astronomical works (eighteen in number) under the name *Siddhāntas* were also composed during this period. Of these, the five namely, the *Paitāmaha Siddhānta*, *Vaśiṣṭha Siddhānta*, *Paulīsa Siddhānta*, *Romaka Siddhānta*, *Saura Siddhānta* (i. e., *Sūrya Siddhānta*, and a few others have survived till now. These works also have gone through different recensions. It is now very difficult to assert what original matters areretained in their present redactions. The above five siddhāntas summarized by Varāhamihra (died 587 A.D.) were written during the early centuries of the Christian era. The *Paitāmaha Siddhānta,* the earliest of the five was perhaps written in 80 A.D., for this year was chosen as epochal year in Varāhamihira's work. The *Vāsiṣṭha Siddhānta* was written prior to 269 A.D. as is shown by the fact that Sphujidhvaja Yavaneśvara, who wrote has *Yavanajātaka* in that year, refers to this work. The other Siddhāntas were written later. During the early centruies of the Christian era the Indians came in contact with the Greeks and Romans, and the Babylonians and Greek astronomical works might have been accessible to them. This accounts for the traces of the Babylonian and Greek influences which are noticeable in the works summarised by Varāhamihira. Neugebauer has shown that some of the astronomical constants in the *Vasiṣṭha* and the *Pauliśa Siddhānta* are inspired by the Babylonian linear astronomy. The *Romaka Siddhānta* and the *Saura Siddhānta* likewise bear traces of the Greek influence. It is rather intriguing to find that the refinements introduced by Euclid and Ptolemy in Greek geometry and astronomy remained unknown to the Indians.

The Early Medieval Period (c. 400-1200 A.D.) represents the period of revival and maximum activity of Indian mathematics and astronomy with systematisation of knowledge. The publication of five *Siddhāntas* may however, be said to have prepared the ground for this Renaissance in Indian astronomy and mathematics. According to Datta however the scientific renaissance in ancient India is entirely indigenous. Whatever be the causes of revival, it led to the growth, development and specialization of the knowledge of mathematics and astronomy. Astronomy which had been a branch of mathematics, and now became a seperate branch of its own under the name of *Jyotiṣa.* Geometry which was originally confined to the *Kalpasūtra* and was a part of *gaṇita* was now distinguished as *kṣetragaṇita* or *rekhāgaṇita.* The knowledge of algebra which was included in the Śulbasūtra now came to be known as *Bījagaṇita* and the knowledge of arithmetic proper came to be known as *Pāṭīgaṇita.* Thus readjusted science of *Gaṇita* consisted mainly of arithmetic, algebra and geometry. The knowledge of trigonometry appeared during this period under the name *Jyotpatti* and was considered as a part of *Jyotiṣa.* In this period, the writings of Āryabhaṭa I (c. 499 A.D.), Bhāskara I (600 A.D.), Brahmagupta (628 A.D.), Lalla (c. 749 A.D.), Mahāvīra (850 A.D.), Vaṭeśvara (904 A.D.), Āryabhaṭa II (c. 950 A.D.), Śrīdhara (c. 860-950 A.D.), Śrīpati (950 A.D.) and Bhāskara II (1150 A.D.) represent landmarks in era of progress in the history of Indian astronomy and mathematics. The *Āryabhaṭa I* is a work of great merit, much superior to that of the earlier siddhāntas. It had won for its author a great name as an original mathematician and astronomer. The Āryabhaṭa school was probably established by him at Aśmaka in Kerala ; Bhāskara I and Lalla were the main exponents of this school. Bhāskara I based his works on *Āryabhaṭīya* and made some additions to Āryabhaṭa I's system to simplify astronomical calculations. The *Brāhmasphuṭasiddhānta* of Brahmagupta used different elements from those of Āryabhaṭa I and was adopted as a standard text book on astronomy in North India. The superiority of Brahmagupta's

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constants was recognised by the followers of Āryabhaṭa I headed by Lalla. The process of modification and improvement of the existing works continued up to the end of the 12th century when Bhāskara II wrote his *Līlāvatī*, *Bījagaṇita* and *Siddhāntaśiromaṇi.*

The late Medieval Period (c. 1200-1800 A.D.) is a period of commentaries and some new developments. In this period Bhāskara II's works became so popular that the scholars of North India perhaps remained satisfied merely with the knowledge thus developed and its preservation and propagation. Several hundreds of commentaries were written on the *Līlāvatī*, *Bījagaṇita* and *Siddhāntaśiromaṇi.* Copies of large number of these manuscripts are now available in the original libraries of India and abroad. Among these, the commentators, Gaṅgādhara, Sūryadāsa, Gaṇeśa, Kṛṣṇa, Raṅganātha, Rāmakṛṣṇa are noteworthy. But a few scholars like Nārāyaṇa Paṇḍita (c. 1356 A.D.), Mahādeva (1400 A.D.) Parameśvara (c. 1360-1455 A.D.), the author of the *Karaṇapaddhati*, Nīlakaṇṭha Somasutvan (c. 1500 A.D.), Jñānarāja (c. 1503 A.D.), Jyeṣṭhadeva (the author of *Yuktibhāṣā*), Munīśvara (c. 1603), Kamalākara (c. 1616 A.D.), Paṇḍita Jagannātha (c. 1657-1750 A.D.) etc. made some original contributions. Due to the advent of Muslims in India and consequent unsettled political conditions further mathematical and astronomical progress came to a halt in North India. However, in the Kerala school scholars like Parameśvara, Nīlakaṇṭha, Jyeṣṭhadeva and a few other scholars continued the traditions more or less unhampered.

II. Some Notable Contributions to the Knowledge of Astronomy and Mathematics by the Indians in Ancient and Medieval Periods

1. *Nakṣatra System*

The system of selecting certain groups of stars providing a stellar frame along the ecliptic played a very important role in ancient time for the study of the positions of the sun and moon. This was known as *Nakṣatra* system in India, *hsius* in China, *manāzil* in Arab etc. It is not yet definitely known whether the system had a common origin or was of independent indegenous origin. While the earliest definite mention of this system is found in India in the *Taittirīya Samhitā* (c. 1200 B.C.) it is found in the case of the other nations at a much later period.

The *Ṛgveda* (c. 1500 B.C.) divides sun's yearly path into 12 main divisions, each consisting of 30 equal sub-divisions.[2] The moon's path was likewise divided into 27 or 28 parts possibly on the basis of the moon's sidereal period which was noted to be 27 or 28 in the *Samhitās.*[3] Each part was represented by one *nakṣatra* (a group of stars or asterism). Thus the *Taittirīya Samhitā* (c. 1200 B.C.) writes:

nakṣatrāṇi rūpam tārakā asthāni

(T.S. VII. 5.25)

i.e., "the *nakṣatras,* the form, and the stars (*tārakā*) are the bones". The names of these nakṣatras are found to occur in the *Taittirīya Samhitā* (27 in number, *abhijit*

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is not mentioned), *Maitrāyaṇī Samhitā* (28 including *Abhijit*), *Kāṭhaka Saṃhitā* (27), *Atharvaveda* (28), *Vedāṅga Jyautiṣa* (27) etc.[4] (T.S. IV. 4.10; MS. II. 13. 20; K.S. XXXIX 13 ; AV. XIX. 7 ; VJ. 18). Some of them *Tiṣyā* (i.e., *Puṣyā*), *Aghā* (i.e., *Maghā*), *Arjunī* (i.e., *Phalgunī*), *Citrā* and *Revati* are earlier mentioned in the *Ṛgveda* (V. 54. 13 ; IV. 51. 47 ; X. 64. 8 ; X. 85. 2.).

Before entering into the problem of common origin hypothesis of the system a list of Indian, Chinese, Babylonian and Arabian lunar mansions are given below[5]:

A list of Indian, Chinese, Babylonian and Arabian Lunar mansions

Indiaṇ (c. 1200 B.C.)	Babylonian (c. 700 B.C.)	Chinese (c. 160 B.C.)	Arabian (c. 500 A.D.)
1. Krittikā, η Tauri	1. Timinnu η Tauri	18. Mao η Tauri	3. At-turaiya η Tauri
2. Rohiṇī, α, θ, γ, δ, ε Tauri	2. Pidnu α Tauri	19. Pi ε Tauri	4. Al-debaran α, θ, γ, δ, ε Tauri
3. Mṛgaśīrṣa $\lambda, \varphi^1 \varphi^2$	3. Sur narkabti, β Tauri 4. Sur narkabti, ζ Tauri	20. Tsui λ, φ Orionis	5. Al-haq'a, $\lambda, \varphi^1, \varphi^2$ Orionis
4. Ārdrā, α Orionis	5. Pūtu'āmi μ Geminorum 6. Putu'ami μ Geminorum	21. Shen, α, β, γ, δ, ε ζ, η, χ Orionis	6. Al-han'a η, μ, ν, γ ξ Geminorum
5. Punarvasu α, β Geminorum	7. Tu'ami, sa re'i γ Geminorum 8. Tu'āmi, α Geminorum 9. Tu'ami, β Geminorum	22. Ching (Southern) μ, ν, γ, ξ λ ζ, ε Geminorum	7. Aḍ-dirā, α, β Geminorum

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India (c. 1200 B.C.)	Babylonian (c. 700 B.C.)	Chinese C 160 B.C.)	Arabian (c. 500 A.D.)
6. Puṣyā, δ, γ, θ Cancri	10. Pulukku, γ, Cancri 11. Pulukku δ Cancri	23. Kuei γ, δ, η, Cancri θ	8. An-natra γ, δ, t Cancri
7. Āśleṣā, $t, \delta, \gamma, \eta, \theta$ Hydrae	12. Rīs arī, t Leonis	24. Liu $\gamma, \delta, \eta, \theta$ Hydrae	9. Aṭ-ṯarf, λ Leonis
8. Maghā, $\alpha, \eta, \gamma, \zeta\ \mu\ t$ Leonis	13. Sarru, α Leonis	25. Hsing α, t Hydrae	10. Al-gabha $\alpha, \eta, \gamma, \zeta$ Leonis
9. Pūrva- phālgunī δ, θ Leonis	14. Mārušarī- buarkat śarri ρ Leonis	16. Chang $\upsilon, \upsilon, \varphi, \mu\lambda, \kappa$ Hydrae	11. Az- zubro, δ, θ Leonis
10. Uttara- phālg. β Leonis	15. Zibbat arī, β Leonis	27. I α Crateris	12. As-sarfa β Leonis
11. Hastā, δ, γ, t Corvi α, β	16. Śīpu, aṟku sa ari β Virginis 17. Śur ardati, γ Virginis	28. Chen γ, t, δ, β η Corvi	13. Al-awwā, $\beta, \eta, \gamma, \delta, t$ Virginis
12. Citrā α Virginis	18. Nabu- ardati α Virginis	1. Chio (Eastern) α Virginis	14. As-simāk α Virginis
13. Svātī α Bootis		2. Khang V, K, λ, μ Virginis	15. Al-ghafr, ι, κ, λ Virginis

India (c. 1200 B.C.)	Babylonian (c. 700 B.C.)	Chinese c. 160 B.C.)	Arabian (c. 500 A.D.)
14. Viśākhā, ι, γ Librae β, α	19. Zibānītu śaśuti α Librae 20. Zibānītu-sailtani β Librae	3. Ti α, β, γ Librae ν	16. Az-zubanay α, β Librae
15. Anurādhā δ, β, π Scorpionis	21. Rīs akrabi δ, β Scorpionis	4. Fang β, δ, π, σ Scorpionis	17. Al-iklīl, δ, π, β Scorpionis
16. Jyeṣṭhā α, σ, τ Scorpionis	22. Habrud α Scorpionis	5. Hsin α, σ, τ Scorpionis	18. Al-qalb, α Socrpionis
17. Mūlam λ, υ, κ, ι, θ η ζ μ, ε Scorpionis	23. Mātu śa kasil θ Ophiuchi	6. Wei ε, λ, μ, η, θ ι, κ λ, υ Scorpionis	19. As-saula, λ, υ Scorpionis
18. Pūrvāṣāḍhā δ, ε Sagittari		7. Chi γ, δ, ε Sag.	20. An-naʻāyim γ, δ, ε, η, φ, σ, τ, ζ Sagittari
19. Uttarāṣāḍhā δ, ζ Sagitt.		8. Nan tou (Northern) μ, λ, φ, σ, τ, ζ Sagitt.	21. Al-balda, Sagitt.
20. Abhijit α, ε, ζ Lyrae	24. Karan sug'ur α, β Capricorni	9. Niu α, β, ξ Capricorni	22. Ad-dabih, α, β Capricorni
21. Śrāvaṇā α, β, γ Aquilae		10. Nü ε, μ, ν Aquaril	23. Bula, ε, μ, ν Aquaril

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22. Śraviṣṭhā β, α, γ, δ Delphini	25. Sug'ur γ Capricorni 26. Sug'ur, δ Capricorni	11. Hsu β Aquaril	24. As-su'ūd, β, ξ Aquarii
23. Śatabhiṣaj λ Aquarii	27. (Riś gu), δ Aquarii (?)	12. Wei α Aquarii	25. Al-albiya α, γ, ζ, η Aquarii
24. Pūrva-bhādra padās α, β Pegasi	28. Śēpu arkū śa gu, Pegasi (?)	13. Shih, α, β Pegasi	26. Ad-dalwu, α, β, γ Pegasi
25. Uttara-bhādra padās γ Pegasi, α Andromedae		14. Pi γ Pegasi α Andromedae	27. Al-Fargh al-tani γ Pegasi, α Androm.
26. Revati ζ Piscium	29. Rikis nuni η (Piscium)	15. Khuei (Western) η, ζ, ε, t, δ, π ν, μ, β Androm.	28. Al-ḥūt, β Andromedae
27. Aśvinī β, γ Arietis	30. Riś Kuṣarikki β Arietis 31. Riś kusarikki α Arietis	16. Lou α, β, γ Arietis	1. An-nath, α, β, γ Arietis
28 Bharaṇī a, b, c Muscae		17. Wei a, b, c Muscae	2. Al-butain a, b, c Muscae

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Arabian : The names of 28 Arabic *manāzils*[6] along the ecliptic ~~first appeared~~ in the 5th century A.D. There is also previous mention of the word *manāzil* in the *Qurān* and of *mazzaloth* or *mazzaroth*, Hebrew meaning *manāzil* in the Book of Job or Book of Kings without any idea of lunar mansion. Leopold de Saussure believes in the derivation of *manāzil* from an Iranian system. Henning[7] observes that the Iranian system itself was introduced into Persia from India, with a new set of names for the lunar mansions and the system was probably applied mechanically merely as a mode of indicating the longitude of the sun, moon and the planets. The introduction of this knowledge was made either under king Shapur I (241-272 A.D.) of the Sassanian Period after the conclusion of the Roman war, who passed an order to collect writings on astronomy and medicine, mathematics and philosophy scattered in India, Greece and elsewhere for their introduction to Avesta or towards the end of the Sassanian period under Khosrou I (590-628 A.D.) or even little earlier[8]. Moreover, 19 of the *manāzils* could be identified with the corresponding Indian *naksatras* (vide table). If the common origin hypothesis be accepted the credit of originating this system goes to the Indians.

Greek : The earliest reference among the Greeks[9] appears in Greek papyrus of 4th century A.D.

Chinese : In China a list of 28 *hsius* first appeared in the *Huai Nan Tzu* (160-150 B.C.) as a lunar zodiac (vide table). Before that the names of only 2, then 4, then 8, then 23 *hsius* were found successively recorded in the texts of the period between 14th to 2nd century B.C. Chu Kho-chin (in 1956) and Needham (in 1959) laid claim for the independent Chinese origin of the system at about 8th century B.C. On the basis of 4 *hsius*, which they conjectured, to have associations with four main palaces in which the heaven along the equatorial circle was divided. Even this explanation which is for from convincing makes the Chinese system of *hsius* four centuries later than that of the Indian. Neverthless Needham[10] writes, "the common origin of three chief systems (Chinese, Indian, and Arab) can hardly be doubted, but the problem of which was the oldest remains". If as Needham believes that there is a common origin of the system, credit for this origin obviously goes to the Indians on the chronological basis. Needham's claim of the origin of the system for the Chinese therefore falls to the ground.

Babylonians : Weber[11], Hommel[12], Oldenberg[13] and others believed in the Babylonians origin of lunar mansions. The Babyloni an clay tablets (mul APIN) of about 700 B.C. record 18 normal stars assigining 3 stars to each of six months not far from the ecliptic, Epping's book mentions the names of 28 normal stars to which 5 more was added on the basis of examination of some more clay tablets. Hommel argued, probably originally there were 24 mansions in the world and compared them with those of other countries. He found agreement in respect of 16 Arabian *manāzils* and believed that the *manāzils* were based on the ancient Babylonian scheme. Of those of the Indian and Chinese, only 10 *nakṣatras* and 3 *hsius* correspond to Babylonian lunar mansions. On the other hand 19 *manāzils* agree to the Indian *nakṣatras* as well as Chinese *hsius*. So it is not Babylon but either India or China which played as an active centre for the diffusion of this knowledge. Thibaut raised the objection against Hommel's arguments by saying that since the object was to select a series of asterisms near the ecliptic, agreement to some extent is quite likely. Moreover, the explanation of the common origin hypothesis on the basis of 24 constellations does not fit at all.

Due to very fact that the Indian system with 28 mansions has been recorded as early as in the 12th century B.C. in the *Taittirīya Samhitā* where as the Babylonian system of 28 mansions is found mentioned in the earliest clay tablet belonging to 7th century B.C., the claim of the Babylonian origin of the system becomes absolutely untenable. The credit for the origin of the system, as stated earlier, undoubtedly goes to the Indian from where the idea might have been borrowed by the other nations or independently developed by them.

2. *Numericals, and Decimal Place-value Concept with Symbol for Zero.*

The early symbolic numerals of the world were of various types. The characters varied to meet the linguistic conditions of the different cultural areas in different parts. The Babylonians developed a sexagesimal place-value system of expressing number with 59 symbols. The Egyptians, Chinese, Greeks, Indian and other nations of antiquity developed various systems of numeration. But the discovery of decimal place-value concept of the Indians with ten symbols—for one to nine and zero in arithmetical operations was perhaps the most remarkable contribution to the origin of arithmetic. To have an idea about this an analysis of the main types of the numerals used by the Ancient Babylonians, Egyptains, Chinese, Greeks, Roman, Indians and Arabians will make it clear.

(*a*) *Babylonians* : The Babylonians wrote with stylus on clay tablets, the result being wedge-shaped characters. The tablets were then baked in the sun. The numbers were usually expressed with the help of a sexagesimal scale. Practically 59 symbols from one to fifty-nine (made by repeating two basis symbols, for one and ten) were used. Wherever a symbol for sixty was required, it was replaced by 1 of the next higher order as follows :

1. $10=1\times60+10=70$
2. $12=2\times60+12=132$

In this way a big number was expressed by 1. 41. 33. 59. 3. 45. This obviously involves an idea of place-value. The numeral system is not very happy, because, a comparatively greater amount of repetition is unavoidable for obtaining a number below fifty-nine. In many cases the numerical value of a symbol had to be determined from the context[14]. In certain tablet 71 is represented by symbols of 1. 10.1 i.e., $1\times60+10+1=71$. The number $171\frac{1}{2}$ is represented by symbols of 2. 50. 1. $\frac{1}{2}$ i.e., $2\times60+50+1+\frac{1}{2}=171\frac{1}{2}$. The symbol for 1. 12 may be expressed as 1. 12. $=4320$ or as 1. $12=72$ or as 1. $12=1\ 1/5$ etc. written sexagesimlly. One of the main disadvantages of the Babylonian place-value notation is due to the lack

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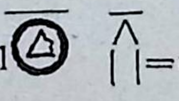
of a symbol for zero. They left an empty space in between two other numeral symbols, for example[15], one misreads a number 1 20 as 1. 20=80 when actually 1. 0. 20=3620 was meant. This gave rise to much confusion for giving any quantitative expression of the numerical value involved as there can be no fixed standard for an empty space to allow for its unambiguous repetitions. It, therefore, helped very little in the symbolic expression of zero in mathematical figures.

(*b*) *Egyptians and the Semetic groups* : The Egyptians used stone, papyrus, wood and piece of pottery for writing. They in their Hieroglyphic system of writing possessed separate symbols for one, ten, hundred, thousand, ten thousand, hundred thousand and million. The Hieratic (religious) and Demotic (popular) system of writings had signs of symbols for one, five to ten, twenty, thirty............to hundred. The Hieroglyphic and Hieratic numbers were commonly written from right to left and also from left to right and sometimes as in early inscriptions from top downwards. The numbers were expressed by repetition and addition of symbolds as necessary. As for example, 23 was represented by 111 UU *i.e.*, 1+1+1+10+10=23. This was also written as UU 1 1 1 . They had therefore little idea of place-value for a symbol.

The phoenicians used the symbols for one, ten, twenty and hundred ; the Palmyrene for one, ten, twenty and hundred. There is no evidence that they had any idea of place-value.

(*c*) *Chinese* : Of the several systems used by the Chinese those of Shang Oracle bone form (14th to 11th century B.C.), Bronze and Coin form (10th to 3rd century B.C.) and the Counting rod form (2nd century B.C. to 4th century A.D.) deserve special notice in this connection. Their symbolic numerals were written usually from top downwards with their values arranged in the descending order.

In the Shang Oracle bone form, separate symbols for one, five, six,seven, eight, nine, ten, twenty, hundred, thousand etc. were used. For two to four, the symbol for one was repeated and other numbers were obtained by similar repetitions. For instance, 162 was expressed by the symbol  =*i.e.*, by symbols of 100, 60 and 2 placed in the left to right order.

In the Bronze and the Coin form (10th century B.C. to 3rd century B.C.) and other forms found in coins of Chou Period (6th to 3rd century B.C.) more or les similar symbols as those or Shang Oracle bone were employed. Neither improvement of method nor use or place-value was known to them.

The Chinese in their counting rod forms between 2nd century B.C. to 4th century A.D. used separate symbols for one, six, ten, sixty. Symbols for one was repeated to express numbers upto five and in values for seven to nine were represented by successive additions of symbols for one to that of six. For the numbers of the next higher order than 100, different symbols were used.

The Chinese in the 8th century A.D. left a gap or some vacant space similar to the Babylonians where a zero was required[16]. A symbol for zero in the usual circular form appeared only in 1247 A.D., in a work *Su Shu Chiu Chang* of Chins Chiu-Shao[17].

(*d*) *Greeks* : The Greeks initially were deeply interested in numbers which were connected with geometric form. They had two other systems of notation —The Attice system and the Alphabetic system. The former, made of upright strokes and initials of several number names, was no better than the system prevalent among the Egyptians and other contemporary civilization. The system was replaced about third century B.C. by the alphabetic system of numerals which were commonly known among the Hebrews, the Syrians, the Arabs,the Persians, and other Semitic people. The alphabetic system had twenty-four letters in their common Ionic alphabet, to which they added, three phoenician alphabets to make it twenty-seven. These are divided into three groups, first nine alphabets denoting nine units, second nine alphabets denoting nine multiples of ten and third nine alphabets denoting nine multiples of hundred. They write from left to right. In writing a compound number, the element of the higher denominations was put first. For example,43, 678 was represented by the symbols δM, γXonφ-i.e. 4000+3000+600+70+8. The Greek astronomical Papyri Mss. (100 B.C.) as well as Ptolemy's table of Chords (150.A.D.) used circular symbol[18] resembling that of modern zero to indicate the ending of a sentence or a marginal gap. But the application of this circular symbol in mathematical calculations could not be traced in any of the ancient contemporary Greek mathematical works and thereafter.

(*e*) *Romans* : The Roman numbers were expressed in terms of symbols for one, five, ten, fifty, hundred, five hundred, and thousand. The normal mode of writing was to put the elements of higher value in the beginning. For example, the number 1548 was written as M C C C C C X X X X V I I I *i.e.*,

1000+500+40+8. In certain cases, it was reversed to denote sbstraction. But in a compound number of still greater value, it will be found that the normal mode has been preserved on the whole. The system had the advantage of using only few symbols for expressing any number in a very simple way. This is the reason why it received a considerable popularity and is still adopted occasionally in numbering the chapters and years of the book.

(*f*) *Indian* : In India, earliest use of symbols for the expression of numbers without the knowledge of decimal place value is provided by Kharoṣṭhi (250 B.C.) and Brāhmī (250 B.C.) inscription.

The Kharoṣṭhī was particularly the script of North-western India (including Afganisthan and the Northern Punjab). It disappeared in the 3rd century A.D. In the Kharosthi numerals, there were separate symbols for one, four,ten, twenty, and hundred. They were written from right to left with lower elements before the higher, For example 113 λ 1=2 + 20 + 100=122 and × 7333 λ 11=4 + 10 + 20 + 20 + 20 + 200=274. But in cases of hundred and its multiples, the symbols for the smaller elements were placed after the symbol for hundred to denote multiplication. All these were common with the principles underlying other systems of Semitic numeral notation which we have discussed before.

The Brāhmī numeral system consisted of separate signs for one and four to nine; two and three were denoted by repetitions of the symbols for one. It had also separate symbols for ten and its multiples as well as for hundreds up to seventy thousand. The plan was indeed, nearly the same, as those of the Demotic and the Hieratic and the Chinese. The symbols were written from left to right beginning with symbols for higher values. For example, 274 was written with the help of the symbols for 200, 70 and 4. The Nānāghat and the Nāsik cave inscriptions amongst few other inscriptions namely Kusāna (150 A.D.), Kshatrapa (200 A.D.) and Gupta (c. 300-450 A.D.) are note worthy. But these types bear a close relations and resemble each other. According to many foreign scholars, both Nānāghat (150 B.C.) and the Nāsik (150 A.D.) characters of numerals form the basis of our third or modern numeral system.

From the time of Saṃhitās, (1500 B.C.), the Vedic Indians used on the basis of a decimal scale without use of symbols; for the expression of numbers: the scale *eka* (1), *daśa* (10), *śata* (10^2), *sahasra* (10^3),.... up to 10^{18} was known, and a large number like, *ṣaṣṭhim sahaṣrā sapta śatāni navatim nava* (60, 799) was expressed by, placing the word- numerals of higher order to be followed by one of lower order in the scale. This successive placing of *sahasra, śata, daśo, eka* for the expression of a large number in left to right order of gradually decreasing values obviously shows that the idea of decimal place-value was implied. From about the 3rd-4th century A.D. onwards, on the basis of same decimal place-value a new type or word numerals with right to left order and another type of symbolic use of the numerals retainedin a left to right order began to be used. These orders were so used possibly for no obvious reason, except for emphasizing the idea that the decimal place-value concept remains unchanged in whatever order (right or left) the numerals are arranged in the scale when the number is always expressed by reading from higher to lower order. That the decimal place-value concept was current before seventh century A.D., has also been attested by Vyāsa[19] (before 700 A.D.) in his philosophical work, *Yogadarśanabhāṣya* (Ch. 3, Sū. 13) thus :*Yathaikā rekhā śatasthāne śatam daśasthāne daśa ekam caikasthāne* i.e., 'a (numerical) sign denotes hundred in the *śata* place, ten in the *daśa* place, and one in the *eka* place'. The very similar language is used by Śañkaracārya (c. 800 A.D.) in his *bhāsya* on the *Vedāntasūtra* (II. 2. 17): *Yathā caikāpi rekhā sthānānyatvena niviśamānaika daśaśatasahasrādi śabda pratyayabhedemanubhavati* i.e., 'one and the same (numerical) sign when occupying different places, is convceived as meaning either one, ten, one hundered, a thousand etc'. These two illustrations establish without doubt that by the time of compositions of these two works, the decimal place, value concept must have been well established and was generally known. This system has appeared amongst the Arabs in the 10th century A.D. From there it went to Europe and it has now been adopted by all the civilized peoples of the world.

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In view of the discovery of the decimal place-value concept in India, it is now generally accepted that the circular symbol for zero as a part of the numerical system is an Indian contribution. However Piṅgala's *Chandahsūtra* (200 B.C.) first mentions the word, *śūnya* in the rules for calculating the number of long and short syllables in a metre of n syllables[30]. The *Pauliśa siddhānta* (200 A.D.) and the *Sūryasiddhānta* (400 A.D.) use word numerals like *śūnya, kha* and their various synonyms, *ākāśa, ambara, vyoma,* etc. as a part of the numerical system based on a decimal place-value. The Kashmirian *Atharvaveda*[31] uses circular dot, sufficiently large, for zero in giving the folio numbers and passage numbers. In the *Bakhshali* Mathematics (400 A.D.) we meet the same circular dot for zero in connection with arithmetical operation. The Sanskrit word, *śūnya-vindu* denoting zero-dot is clearly stated is Subandhu's *Vāsavadattā* (c. 600 A.D.). In Malay inscription at Palemlang (684 A.D.), circular zero is used in writing 606 and 60. In another Malay inscription at Kotakapur (716 A.D.), the number 608 is expressed with circular zero[22]. At Java, Champa, Malaya etc. there were Indian and Chinese Colonisation. In this connection scholars like Needham argue that the origin of the symbol for zero should be attributed to the mixed culture of the Indians and the Chineso But such an argument is quite untenable in view of the fact that the use of the symbol for zero fitted in a decimal place-value scale appears in China only in the Ms. of the 13th century A.D. Furthermore, there is no evidence that the use of the word numerals including that of zero in a decimal place-value scale, as it is found at Java, Malay etc., was ever made by the Chinese or even by any other nations except by the Indian prior to their symbolic use.

Thus there is enough ground to believe that the system of numerals with nine symbols from one to nine and the symbol for zero on the basis of the decimal place-value concept developed in India before 700 A.D. According to Sarton[23], "our numerals and the use of zero were invented by the Hindus and transmitted to us by the Arabs (hence the same Arabic numerals which we often give them)".

(g) *Arabic* :- Arabians in writing out a number in full, followed either the ascending or descending order. But in their notations they consistently followed the descending order. There are numerous applications of the alphabetic numerals in Al-Bīrūnī's *Chronology of Ancient Nations*[24]. In every instance the higher denomination has been put before the lower. In the tenth and a few following centuries it is found that several mathematical works were composed by the Arab scholars having titles containing the words, *al-hind, al-hindi, al-takht, al-ghobar*. These contained methods and systems very closely resembling those of the Indians [25]. It is, therefore, *not unlikely that* the Arabs derived their knowledge of decimal place-value notations from Indians. Furthermore, Abu Sahl ibn Takim (c. 950 A.D.) in his commentary on the *Sefer Yesirah* admits that "*one* Hindus have invented the nine signs for making the units, I have spoken sufficiently of them in a book that I have composed on the Hindu calculation known under the name of *Hisāb al-ghobar*." Al-Bīrūni (1030 A.D.) the well known Encyclopaedist made the following observation in his *India*[26], "The numerical signs which we use are derived from the finest of the Hindu signs".

As regards sign of zero al-Bīrūni (973-1048 A.D.) writes[27], "when zero has to be written in places lacking a number, its circle must have a line over it Ō, touching to distinguish from *hā*, but in the Indian notation, this is unnecessary for there is no resemblance to *hā*". This approves the Indian use of circular symbol, 'O'. The dot symbol (.) was also used by Bīrūñi's.[28] Thus new edition of the Encyclopaedia writes (1965) "The full development of the concept of zero has been credited to the Hindus, from whom Arabic scholars seem to have taken the notion. Medieval Latin writers on Arithmetic translated or transliterated the Arabic word as *Zephyrum*; this in Italian took as such from as Zeuero, Zeuero, and became contracted to zero. The term was borrowed as zero by the Fernch, who contributed it to the English language".

3. *Square root and Cube root*

Special credit is given to Āryabhaṭa I (c. 479 A.D.) for this rules for the extraction fo the square and cube roots developed on the knowledge of decimal place value concept. His rule for square root extraction runs thus :

bhāgaṃ haredavargānnityaṃ dviguṇena vargamūlena |
vargādvarge śuddhe labdhoṃ sthānātare mūlam ||

(*Āryabhaṭiya, ii.* 4)

"Divide always the non-square (*avarga*) places by twice the seqare-root (upto the preceding odd place); after having subtracted the square (of the quotient) the odd place (*varga*), then the quotient placed at the separate place gives the root"

That is, the number whose square-root is to be determined, is to be divided *varga* (square place) and *avarga* (non-square place) respectively from right, and the rule can be explained from the following illustration by putting □ and—marks against square and non-square places. Modern method of square root extraction is also given side by side for the purpose of comparison.

	Āryabhaṭa's method	*Modern method*
[29]	□ — □ — □ 5 4 7 5 6 (root 2)	5 $\dot{4}$ 7 $\dot{5}$ $\dot{6}$ 234
Subtract the square 2^2=	4 ...... (1)	4 - - (1)
Divide by twice the root *i.e.*, 2×2 =	4) 1 4 (3 .... (a) root 23 1 2 2 7	43 1 4 7 1 2 9 ... (2)
Subtract square of the quotient 3^2 = 9	9 ....(b) (2)	464 1 8 5 6 1 8 5 6(3)
Divide by twice the root *i.e.*, 2 X 23	46) 1 8 5 (4....(a') 1 8 4	
Subtract square of the quotient *i.e.*, 4^2=16	1 6 1 6.... (b') (3)	

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This shows that the modern method of extracting square root is same as that of Āryabhaṭa I (c. 499 A.D.) with the only difference that stages numbers (2) and (3) in the working of the modern method were carried out in two distinct steps.[30] His rule for the cube root extraction is also given in *Āryabhaṭīya*[31] (ii.5).

The Knowledge in other Cultural Areas

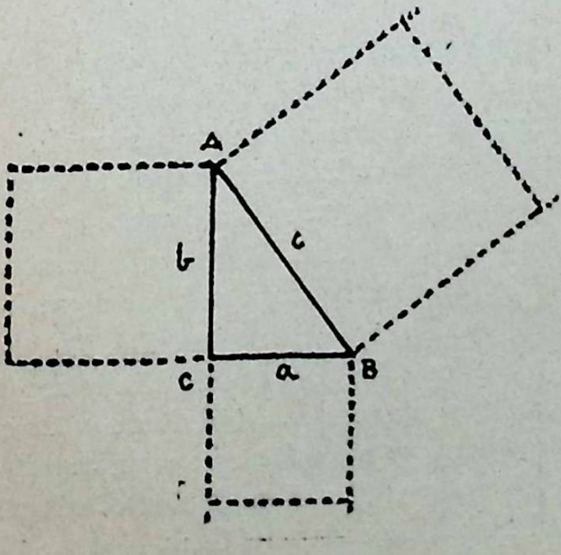
The Chinese tried to find the square-root (*Khaifang*) and cube-root (*Khai li fang*) in the first century A.D. by geometrical methods different from those of Āryabhaṭa I and had hardly any success in formulating a rule upto 12th century A.D.[32]

In Europe these methods do not appear before Cataneo (1546 A.D.). It is Cataneo who gives a method which is exactly the same as that of Āryabhaṭa I.[33] In the 4th century A.D. Theon of Alexandria[34], the well-known commentator of Ptolemy's *Almagest* found the square-root of 4500 to be 67° 4′ 55″ in sexagesimal unit without mentioning any method for finding the whole number 67. In another place, he explained $144=10^2+2.\ 10.\ 2+2^2=(10+2)^2$ with the help of a diagram to illustrate probably the Euclidean formula : $a^2+2ab+b^2=(a+b)^2$. This shows that Theon's method was algebraical and different from Āryabhaṭa's method.

4. *The Theorem of Square on the Diagonal*

The theorem : $a^2+b^2=c^2$, where a, b, and c are the perpendicular, base and hypotenuse of a right-angled triangle, is now universally associated with the name of Greek Pythagoras (c. 540 B.C.), though there is no evidence that he discovered the general statement of theorem. The general enunciation of the theorem was first made in India by the *śulbakāra* (altar-maker) Baudhāyana (c. 600 B.C.) who was contemporaneous with Pythagorus, if not earlier, In the *Baudhāyana Śulbasūtra* the following lines occur :

> *dīrghacaturaśrasyakṣṇayā rajjuḥ pārśvamānī tiryaṅmānī ca yat pṛthagbhūte kurutastadubhayaṃ karoti* |
>
> (*Baudhayānaśulba*, i. 48)



"The diagonal of a rectangle produces both (areas) which its length and breadh produce separately". That is, the square described on the diagonal of a rectangle has an area equal to the sum of areas of the squares described in its two sides (Fig. 1).

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The proposition is stated in almost identical terms also by Āpastamba and Kātyāyana[35].

This statement was made in connection with the construction of different altars, i.e., brick structures of considerable size and shape. The sacrifice was the prime religious avocations of the Vedic Hindus. The Kalpasūtras contain besides other matters of rituals, the rules for the proper construction of sacrificial altars. It was *perhaps* in this connection that the study of the problems of geometry as also arithmetic and algebra began in ancient India. Besides many other duties of altar construction, the śulbakāras had to perform several important duties systematically viz., i) to clean and level a plot on which the altar is to be constructed ii) to fix east-west line (*Prācī*), for it was considered as the reference lline, iii) to construct bricks of specific sizes, (iv) to draw diagrams of specific sizes on the level ground on which the altar is to be constructed, v) to lay bricks subject to certain principle. To perfrom these duties many specialists arose to solve construction problems which required good deal of knowledge of geometry and mathematics

The thorem was beautifully discussed by Būrk who concluded that Pythagoras theorem was known and proved in all its generality by the Indians long before the date of Pythagoras[36]. He went further that, so far from Indian Geometry being indebted to the Greeks, the much travelled Pythagoras probably obtained his theory from India[37]. His paper attracted criticism from Zenthen, Cantor and Vogt. Later on, the criticism has been extended as charge by Cajori[38] and Heath[39], which can be summarized as follows :

1. The general statement appears to have been the result of an imperfect induction from a very small number of cases of right-angled triangles in rational numbers known to them.

2. They gave no proof.

The charge regarding item 1 is that the general statement is the result of an imperfect indirection from a very small number of cases of right-angled triangles having sides in rational numbers. The number of examples may be small. But to prove the general truth of the theorem one has to find instances of i) general arithmetical character i.e., its application to cases of rectangles whose sides can be expressed by both rational and irrational quantities and ii) general geometrical character. If this be proved, there cannot be absolutely any doubt as regards the recognition of truth of the most general character of the theorem. Dr. Datta has discussed beautifully the subject as regards the knowledge of both the items and concluded that general truth of theorem was understood by them. Ancient Indians were not in the habit of giving any proof, so was the case with *Sulbakāras*. Many proofs were conjectured by Bretschneider, Heath and Datta. Bretschneider's proof has also been accepted by Hankel, Allman and Gow.

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Greek : Many conjectured proofs are also associated with the name of Pythagoras (c. 540 B.C.). Actual proof was first given by Euclid (c. 300 B.C.). Proclus (c. 460 A.D.), the commentator of Euclid remarked : "for my part, while I admire those who first observed the truth of the theorem, I marvel more at the writer of the *Elements*, not only because he made it first by a most lucid demonstration, but because he compelled assent to the still more general theorem by the irrefragable arguments of science in the sixth book[40]. Heath admitted with remarks "It is difficult for us to be more Positive than Proclus was"[41]. Hence it is far from conclusive than Pythagoras stated the above general theorem.

Babylonian : Variety of evidence is at present available that practical use of the theorem was current in old Babylonian times (c. 1800-1600 B.C.). The evidence for this is found in certain Babylonian cuneiform tablets. No general theorem was found to have been mentioned. It has conclusively been proved by Neugebauer that Pythagoras has derived his "Number theorem of universe" as well as so called Pythagoras theorem from the cuneiform tablets.[42].

Chinese : The Chinese knew a similar relation which appeared in Chou Pei (4th century B.C.) and most of its credit is connected from the time of its first commentator Chao Chun Chhing (2nd century A.D.)[43].

In India the proof first appeared in the work of Bhāskara II[44] (c. 1150 A.D.). Needham remarks, "Bhāskara's treatment derives from the Chou Pei"[45]. But Datta has shown that there was quire a number of construction described in the Śulbasūtras from which the proof of the theorem can readily be deduced.[46]

5. *Value of* $\sqrt{2}$

The discovery of the value of $\sqrt{2}$ correct to five places of decimals is another great achievement of the Indians in the sixth century B.C. The value was first given by Baudhāyana (i. 61-2) who was followed by Āpastamba(1.6.) and Kātyāyana (2. 13) almost in identical language, which runs thus :

pramānaṃ tṛtīyena vardhayettacca caturthena
ātmacatustriṃśonena, saviśeṣa!
(*Baudhāyana Sulba. i.* 61-62)

"Increase the measure by its third and this third by its own fourth less the thirty-fourth part of that fourth. This is the value (of *Dvikaraṇī* i.e., $\sqrt{2}$) with a special quantity in excess".

This gives—
$$\sqrt{2}=1+\frac{1}{3}+\frac{1}{3.4}\qquad\frac{1}{3.4.34}\quad\text{(approx.)}$$

In terms of decimal fractions, this becomes $\sqrt{2}=1.4142156$. According to modern calculation $\sqrt{2}=1.414212\ldots\ldots\ldots$ Thus it is clear that the ancient Hindus attained a very remarkable degree of accuracy in calculating an approximate value of $\sqrt{2}$ by geometric method. A method of calculation for arriving at this value was given by Thibaut. Datta has explained that the rule due to Baudhāyana, Āpastamba, and Kātyāyana giving the values of $\sqrt{2}$ implies a beautiful geometrical method for its calculation.[47] This method consists in constructing a square with area equal to the sum of the areas of the two other squares having sides of one unit in length. For this, one of the two squares having side of unit length is divided into three equal parts by lines drawn parallel to one of its side. Each of these parts forms a rectangular piece of one unit in length and one-third unit in width. Two of these rectangular parts are then joined lengthwise to the two adjacent sides of the other unit square. This leaves a square hole at one of the corners of the enlarged unit square. This square-hole will have side of one-third unit in length. remaining rectangular piece of the divided unit square is again sub-divided into three equal parts each forming a square of side one-third unit in length. One of these squares is fitted into the square-hole formed at one of the corners of the enlarged square. Each of the remaining two squares is again sub-divided into four equal rectangular pieces having length of ⅓unit and width of $\frac{1}{3.4}$ unit. Eight of these small rectangular slips are placed lengthwise side by side on the two adjacent sales of the enlarged square with four on each side. This again leaves a square-hole at the corner having a side of length $\frac{1}{3.4}$ unit. Now two equal thin slips have to be deducted from the two adjacent sides of the enlarged square under constructions, the width of each of the slips is therefore given by

$$\frac{\left(\frac{1}{3.4}\right)^2}{2\times\left(1+\frac{1}{3}+\frac{1}{3.4.}\right)}=\frac{1}{3.4.34}$$

Hence the side of the desired square is given approximately by $1+\frac{1}{3}+\frac{1}{3.4}\quad\frac{1}{3.4.34}$ which gives the value of $\sqrt{2}$. This method is simpler and straightforward than that of Thibaut.

Babylonian: In Babylon a small cuneiform tablet of the old Babylonian times (c. 1800-1600 B.C.) is now traced in the Yale Babylonian collection (No. 7289) which shows a square with its two diagonals.[48] Three numbers in sexagesimal system are inscribed on it. These three numbers are represented by Neugebauer[49] as the value of diagonal, a side and the value of $\sqrt{2}$ (since d=2 a). Here $\sqrt{2}=1;$ 24, 51, 10. Now Hindu value $\sqrt{2}=1+\frac{1}{3}+\frac{1}{3.4}+\frac{1}{3.4.34}$ —if changed into sexagesimal unit gives $\sqrt{2}=1, 24, 51, 10, 36$ ——. Has the Hindu system of calculating the value of $\sqrt{2}$ developed from that of the Babylonians? Two points are important in this connection so far as the Hindu origin is concerned : i) In the period, there is no use of sexagesimal system, ii) the rule is clearly stated thus :"the side of a square is to be increased by its third, the third again by its fourth part less its (fourth part's) thirty-fourth part".[50] We have no evidence of any such method of which the Babylonians were aware.

Greek: As regards Greek sources, many approximations to the values of $\sqrt{2}$ were current but such a correct approximation of $\sqrt{2}$ did not occur[51].

6. *Indeterminate Equations of the First Degree*

Indians attained a general solution of the indeterminate equations of the type by=ax±c. Some scholars[52] attributed the credit for the solution of this type of equation to the Greeks and others[53] to the Chinese; Indian interest in indeterminate problem has been traced to the *Śulbasūtras* (500-400 B.C.) together with a complete rational solution by Āryabhaṭa I (c. 429 A.D.); the Greek and the Chinese made partial reference to the topic in the 1st and 4th century A.D. respectively.

For the construction of square-shaped altar (*Gārhapatya vedi*) having five layers of bricks the Indian *śulbakāra* (geometrician) Baudhāyana prescribes that each layer must be made of two types of 21 square bricks. This leads to the similtaneous indeterminate equation of the following type in first degree :

$$x + y = 21$$

$$\frac{x}{m^2}+\frac{y}{n^2} = 1$$

where m, n are integral parts of the altar.

Baudhāyana gives the following set of values :

1) $m=6, \quad n=4, \quad x=9, \quad y=2$
2) $m=3, \quad n=6, \quad x=5, \quad y=16.$

This and a few other problems given in the *Śulbasūtras* indicate without doubt an interest in Indeterminate problems as far back as 5th century B.C.

Āryabhaṭa I (c. 499 A.D.) first gave rule for obtaining a general soultion of the problem by=ax±c. His rule runs thus :

adhikāgrabhāgahāraṃ chindyādūnāgrabhāgahāreṇa |
śeṣaparaspara-bhaktaṃ matiguṇamagrāntare kṣiptam ||
addauparigunitamantyayugūnāgracchedabhājite śeṣam |
adhikāgracchedaguṇam dvicchedāgramadhikāgrayutam. ||
(*Āryabhaṭiya*, ii. 32-3)

Datta's translation[54] :—

"Divide the divisor corresponding to the greater reminder by the divisor corresponding to the smaller remainder. The residue (and the divisor corresponding to the smaller remainder) being mutually divided, the last quotient should be multiplied by an optional integer (*mati*) and then interpolated (*kṣiptam*) by the difference of the remainders. Any number below (*i.e.* the penultimate) is multiplied by the one just above it and then added by that below it. Divide the last remainder (obtained by doing so repeatedly) by the divisor corresponding to the smaller remainder; then multiply the residue by the divisor corresponding to the greater remainder and add the greater remainder. (The result will be) a number corresponding to the two divisors".

The rule is obviously intended for the solution of the following problems:

(1) To find the number N, which when divided by a given number *a* will leave a remainder r_1 and when divided by another given number *b* will leave a remainder r_2.

(2) To find a number (N) which being divided severally by the given numbers $a_1, a_2, a_3, \ldots\ldots a_n$ leaves as remainders $r_1, r_2 \ldots\ldots\ldots r_n$ respectively.

In modern notation, this can be written as,

1) $N=ax+r_1=by+r_2$.

2) $N=a_1x_1+r_1=a_2x_2+r_2=a_3x_3+r_3=\ldots\ldots\ldots+a_nx_n+r_n$.

Āryabhaṭa I keeps $c=r_1-r_2$ always positive. Consequently his rule is directed to solve an equation of the form.

i) $y=\frac{ax+c}{b}$ if $r_1 7 r_2$ and ii) $x=\frac{by+c}{a}$ if $r_2 7 r_1$

Here a, b=divisors, *bhāgahāra*, *bhājaka*, *cheda*, etc.

r_1, r_2=remainders, *agra*, *śeṣa*, etc.

Detailed rules of solution are also given by Āryabhaṭa I (499 A.D.), Bhāskara I (522 A.D.), Brahmagupta (628 A.D.), Mahāvīra (830 A.D.), Āryabhaṭa II (950 A.D.), Bhāskara II (1150 A.D.) and by later authors and commentators. Further we find that Āryabhaṭa I himself has admitted that he was discussing the knowledge current in Kusumapura[55] (found in the 1st century B.C.). The process *thus* has a long history behind it and did not appear all of a sudden in a fully developed form.

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Greek : Regarding Greek contribution, Nicomachus of Geresa[56] (1st century A.D.) gave an example on the problem of remainders involving linear indeterminate analysis. Diophantus[57] (3rd century A.D.) discussed the indeterminate equation of the second degree and higher degrees but did not deal equation of the first degree. Kaye[58] has admitted that prliminary notions, responsible for the evolutions of the rule are not found common in both Indian and Greek works. *This shows* that Greek mathematicians had therefore hardly any real interest in the indeterminate equations in the first degree like that of the Indians, who considered the subject as an important branch of algebra.

Chinese : The basis of the Chinese contribution is placed on the following example of the *Sun-Tsu Suan-ching*[59] (4th century A.D.). "There are certain things whose number is unknown. Repeatedly divided by 3, remainder is 2; by 5 the remainder is 3; and by 7, the remainder is 2. What will be the number?" No process of finding them has been indicated. The solution can easily be obtained by insepction. The application of the equation: $by=ax\pm c$ was first found in a calendrical work, *Ta-yenli* of I-Hsing (683-727 A.D.) a *Tantric Buddhist astronomer.* I-Hsing is again a contemporary of Chu-tan Hsi-ta, a Hindu Chinese astrologer who translated among others a Sanskrit calendar under the Chinese title *Chu-chih-li.* I-Hsing's method *Ta-yen-shu* was very much similar to that of the Indians. Hence *it is not improbable* that I-Hsing *bodily incorporated* the Hindu method in his *Ta-yenli*. Moreover, according to Sarton[60] the penetrations into China of Indian mathematical and astronomical ideas had started for more than a hundred years before the time of Hsi-ta and I-Hsing.

7. *Binomial Theorem* :

The credit of expansion of Binomial theorem :

$$(a+b)^n = a^n + n^c{}_1 a^{n-1} b + n^c{}_2 a^{n-2} b^2 + \ldots\ldots\ldots + b^n.$$

in its simplest form i.e., when n is a positive integer, goes to India[61] and it is the Indian scholar Halāyudha (10th century A.D.) who established it much before the Chinese and European scholars could do anything about it. It is based on a concept which developed in India in association with the problem of making verses of different metres (*chandas*) in a poetical composition. The *Varṇasaṅgīta* (the music of sound variations) of the Vedic and post-Vedic composers depended only on the variation of two sounds namely *guru* (long) and *laghu* (short) sounds. Piṅgala (200 B.C.) in his *Chandaḥsūtra* described clearly a rule of finding the variation of sounds of syllables in a particular metre. For example, in a three syllabic *madhyā chanda* based on *guru* and *laghu*, the variations of *guru* and *laghu* will be— three *guru* sounds will occur once, two *guru* and one *laghu* sound will occur thrice, one *guru* and two *laghu* sounds occur thrice, three *laghu* sounds will occur once. If we take *guru* as *a* and *laghu* as *b* then it gives $(a+b)^3 = 1.a^3 + 3a^2b + 3ab^2 + 1.b^3$. Similarly for a four syllabic *Pratiṣṭhā chanda*, it uses $(a+b)^4 = 1.a.^4 + 4a^3b + 6a^2b^2 + 4ab^3 + 1.b.^3$. The technique of finding the number of variation of sounds was actually practised by Piṅgala and other Vedic composers to detect the quality as well as short comings of the metres.

Halāyudha (10-11th century A.D.) in his commentary on the Piṅgala *Chandaḥ-sūtra* (ch. 8, verse 34) introduced a *meruprastāra* (pyramidal scheme) technique with the coefficients of the different variations in the expansion of $(a+b)^1$, $(a+b)^2$, $(a+b)^3$......to minimise the trouble of computing the different layers which run thus :

"Draw a square on the top, two squares are drawn below (side by side) so that half of each is extended on either side. Below it three squares, below it (*again*) four squares are drawn and the process is repeated till the desired pyramid is attained. In the (topmost) first square the symbol for one is to be marked. Then in each of the two squares of the second line figure one is to be marked. Then in the third line figure one is to be placed on each of the two extreme squares. In the middle square (of the third line) the sum of the figures in the two squares immediately above is to be placed; this is the meaning of the term pūrṇa. In the fourth line one is to be placed in each of the two extreme squares. In each of the middle squares, the sum of the figures in the two squares immediately above that is, three is placed. Subsequent squares are filled in this way. Thus the second line gives the expansion of combinations of (short and long sounds forming) in a one syllabic metre; the third line the same for two syllables, the fourth line for three syllables and so on". (*vide* Fig. 2).

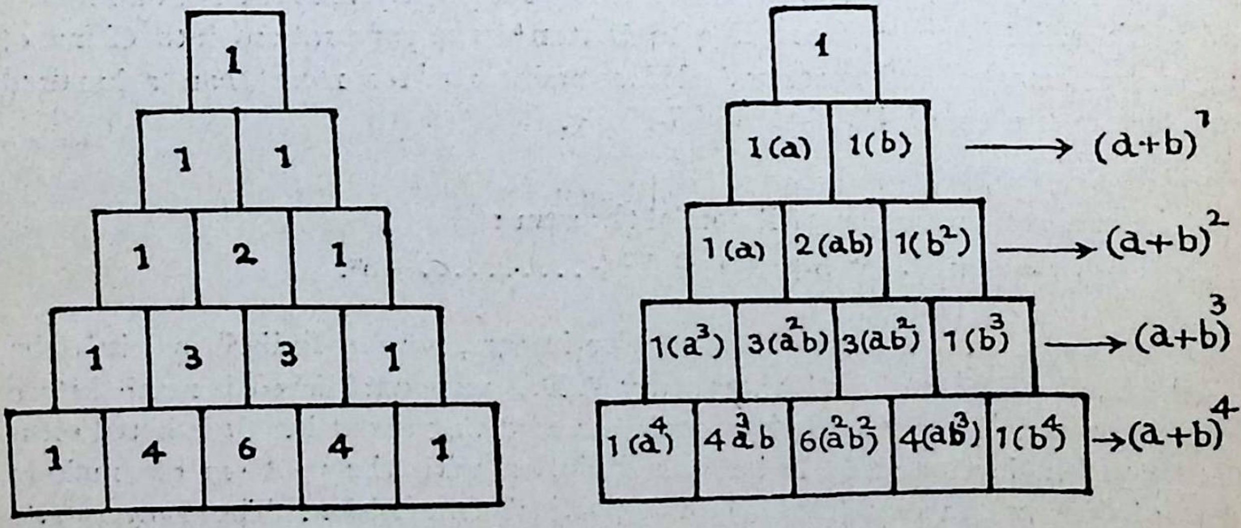
1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1
1(a) 1(b) → (a+b)¹
1(a) 2(ab) 1(b²) → (a+b)²
1(a³) 3(a²b) 3(ab²) 1(b³) → (a+b)³
1(a⁴) 4a³b 6(a²b²) 4(ab³) 1(b⁴) → (a+b)⁴

Fig. 2. Meruprastāra

In modern notation this gives to ,

$$1$$

$$^{1}c_{0} \quad ^{1}c_{1} \qquad \longrightarrow \qquad (a+b)^{1}$$

$$^{2}c_{0} \quad ^{2}c_{1} \quad ^{2}c \qquad \longrightarrow \qquad (a+b)^{2}$$

$$^{3}c_{0} \quad ^{3}c_{1} \quad ^{3}c_{2} \quad ^{3}c_{3} \qquad \longrightarrow \qquad (a+b)^{3}$$

$$^{4}c_{0} \quad ^{4}c_{1} \quad ^{4}\delta_{2} \quad ^{4}c_{3} \quad ^{4}c_{4} \longrightarrow \qquad (a+b)^{4}$$

In this way, the general expansion of

$(a+b)^n=a^n+n_{c_1}a^{n-1}b+\ldots\ldots\ldots\ldots+b^n$ was readily obtained for a metre of n syllables.

The very same technique of arriving at the triangular array appeared in China in the work *Ssu Yuan Yū Chien* (1303 A.D.) ('the old method chart of seven multiplying squares') of Chu Shih Chieh and in Europe in the publication of Pascal's *Traitē du Triangle arithmetic* (1655 A.D.). The Triangle, however, appeared in Europe more than hundred years before the *Traitē* on the title page of the arithmetic of Apianus (1527 A.D.), and in the works of Stifel (1544 A.D.), Scheubel (1545 A.D.), Tartaglia (1556 A.D.), Bombelli (1572 A.D.) and others[62], but about four centuries later befor it actually appeared in India.

8. *Trigonometry*

The work of Hipparchus (c. 150 B.C.), Menelaus of Alexandria (c. 100 A.D.) and Ptolemy (c. 150 A.D.) in connection with the astronomical problems in the early Christian era led to the growth of trigonometrical knowledge in Greece in a rather fragmentary character.

It was however the Indians at a later date (4th to 12th century A.D.) who developed the subject in a systematic manner almost resembling its modern form This was then transmitted to Arabia by the beginning the of 9th century A.D. The Arabian scholars introduced some further improvement. From the Arabs, the knowledge went to Europe where a detailed account of trigonometrical knowledge first appeared in the work *De Triangulīs* of Rtegionomtanus (1533 A.D.).

Preliminary Indian methods in plane trigonometry :—

(1) *Trigonometrical functions*:—In India in the works of Āryabhaṭa (499 A.D.), and Varāhamhira (503 A.D.) the study of properties of the right angled triangle inscribed in a circle in connection with the use of gnomon in astronomical measurement was given much importance. The circle was divided into four quadrants and circumference into many equal parts. Three functions, *jyā*, *kojyā* and *utkrama-jyā* were used in the development of this new geometry known as plane trigonometry.

The modern equivalents of these functions (Fig. 3) are as follows:

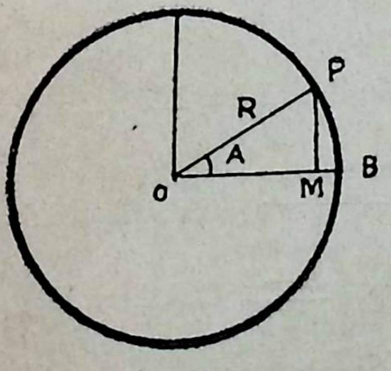

Fig. 3

jyā A=PM=R Sin A

kojyā A=OM=R Cos A

utkramajyā A=MB=R—R Cos A

=R (1—Cos A)

=R Versin A where R is the Radius of the circle.

(2) *Calculation of R Sin A*, $A \leqslant 90°$.

Varāhamihira (c. 505 A.D.) in his *Pañcasiddhāntiikā* (ch. 4, v. 19) gave the following formulae :

$$R \text{ Sin } 30° = \frac{R}{2}$$

$$R \text{ Sin } 60° = \frac{\sqrt{3}}{2} R$$

$$R \text{ Sin } 90° = R = 120°$$

$$(R \text{ Sin } A)^2 = \frac{R}{2}\left[R\text{-}R \text{ Cos} 2A\right]^2$$

and $R \text{ Sin}^2 A^2 + R^2 \text{ Cos}^2 A = R^2$

With the help of these formulae Varāhamihira perhaps calculated the values of '4 *Jyā* lengths or R Sines ranging from 3°45' to its 24 multiples.

Bhāskara I (c. 600 A.D.) in his *Mahābhāskarīya* (vii. 17-19) has also stated the following approximate formula for calculating the R Sine of an acute angle without the use of a table.

$$R \text{ Sin } A = \frac{R(180° - A)\, A}{[40500\text{-}(180° - A)\, A]\,/4}$$

where A is in degrees.

This formula in modern notation may be written as :

$$\text{Sin}\lambda = \frac{16\lambda\ (\pi - \lambda)}{5\pi 2 - 4\lambda\ (\pi - \lambda)}$$ where λ radians correspond to A degrees.

Putting $\lambda = \pi/3,\ \pi/4$, and $\pi/7$, we gets Sin $(\pi/3)$.=8648; Sin $(\pi/4)$ =·70058...... and Sin $(\pi/4)$—·4313.. .which are correct upto 2 places of decimals. The values of Sinπ, Sin $\pi/2$, and Sin $\pi/6$ come out to be accurate.

(3) *Calculation of R Sin* A, $A > 90°$.

Varāhamihira (505 A.D.), Bhāskara I (c. 600 A.D.), Brahmagupta and others have made use of the following formulae :

$$\left.\begin{array}{l} R \text{ Sin } (90° + A) = R \text{ Sin } (90° - A) = R \text{ Cos } A \\ R \text{ Sin } (180 + A) = - R \text{ Sin } A \\ R \text{ Sin } (270° + A) = - - R \text{ Sin } (90° - A) = - R \text{ Cos } A \\ \qquad\qquad\qquad \text{where } A < 90° \end{array}\right\} \text{(Bhāskara I)}$$

$$R^2 \text{ Sin}^2 A = \frac{R}{2} (R - R^2 \text{ Cos}^2\, 2A) \qquad \text{(Varāhamihira, Bhāskara I)}$$

$$R^2 \text{ Sin}^2 A \quad \left[\frac{R \text{ Sin}^2 2A}{2}\right]^2 + \left[\frac{R - R \text{ Sin } (\frac{\pi}{2} - 2A)}{2}\right]^2 \qquad \text{(Varāhamihira)}$$

$$\tfrac{1}{2}\sqrt{(R\text{Sin } A\text{-}R \text{ Sin } B)^2 + (R \text{ Cos } A - R \text{ Cos } B)^2} = R\text{Sin } \frac{A - B}{2} \qquad \text{(Bhāskara II)}$$

$$R \text{ Sin } (A \pm B) = \frac{R \text{ Sin } A.\ R \text{ Sin } B}{R} \pm \frac{R \text{ Sin } B \times R \text{ Cos } A}{R} \qquad \text{(Bhāskara II)}$$

(4) *Expansion of* π, *Sine, Cosine and Tan functions in series*:-

Activity towards the expansion of π, Sine, Cosine and Tan functions in infinite series started in Europe in the works of Gregory (1638-1675 A.D.), Newton (1642-1727 A.D.),De Moire (1667-1754 A.D.) and others in the 17th century while in India it was started about one century earlier in the works of Mādhava, *Karaṇapaddhati* (16th century), Nīlakaṇṭha (1500 A.D.) and *Yuktibhāṣā*.

The Sanskrit works give the expansion of π, Sine, Cosine and Tan functions as follows:

1) $\pi/4=1-\frac{1}{3}-\frac{1}{5}-\frac{1}{7}-\ldots\ldots.$

2) $\text{Sin}\theta=\theta-\frac{\theta^3}{31}+\frac{\theta^5}{51}-\ldots\ldots\ldots$

3) $\text{Cos}\theta=1-\frac{\theta^2}{21}+\frac{\theta^4}{41}-\ldots\ldots\ldots$

4) $\theta=\left[\frac{\text{Sin}\,\theta}{\text{Cos}\theta}\right]-\frac{1}{3}\left[\frac{\text{Sin}\theta}{\text{Cos}\,\theta}\right]^3+\frac{1}{5}\left[\frac{\text{Sin}\,\theta}{\text{Cose}\,\theta}\right]^5-\ldots\ldots$

where $0\leqslant 45°$.

π—Series

The following lines are given by Mādhava (1350-1460 A.D.).

vyāse vāridhinihate rūpahate vyāsa sāgarābhihate
trisarādi viṣamasaṃkhyābhaktamṛṇaṃ
svaṃ pṛthak kramāt kuryāt
labdhaḥ paridhiḥ sūkṣmo bahukṛtvo haraṇato'
tisūkṣma syāt

(vide. *Kriyākramakarī*, Section on circle, II. 40).

This gives the value,

$$\frac{\pi}{4}=1-\frac{1}{3}+\frac{1}{5}-\frac{1}{7}\ldots\ldots\ldots\ldots\ldots\pm\frac{1}{n-2}\;\frac{1}{n}-\pm\frac{1}{n-2}$$

First verse of the chapter 6 of the *Karoṇapaddhati* runs thus :

vyāsāccaturghnād bahuśaḥ pṛthaksthāt
tripañca saptadyayugāhṛtāni |
vyāse caturghne kramaśastvṛṇam svaṃ
kuryāt, tadā syāt paridhiḥ susūkṣmah ||

(*Karaṇapaddhati*, ch 6, v. 1)

"Four times of the diameter is to be divided separately by each of the odd integers 3, 5, 7............, every quotient whose order is even, is taken away from the one preceding it. Combined result of all such small operations when subtracted from four times the diameter, gives the value of the circumference with progressively greater accuracy".

If C be the circumference and D the diameter, the rule may be expressed as:

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$$c = 4D - 4D\left(\frac{1}{3} - \frac{1}{5}\right) - 4D\left(\frac{1}{7} - \frac{1}{9}\right)\cdots\cdots$$

$$\text{or } \pi/4 = \left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} \ldots\ldots\ldots\ldots\ldots\ldots\right);$$

Another verse runs thus :

vargairyujāṃ vā dviguṇairnirekair
vargākṛtairvarjitayugmavargaiḥ |
vyāsaṃ ca ṣaḍghnaṁ vibhajet phalaṃ svaṃ
vyāse trinighne paridhistadā syāt
(*Karaṇapaddhati*, ch. 6, v. 4)

"Six times the diameter is divided separately by the square of twice the squares of even integers (2, 4, 6........) minus one, diminished by the squares of the even integers themselves. The sum of the resulting quotients increased by thrice the diameter is the circumference".

Thus,

$$c = 3D - 6D\left[\frac{1}{(2.2^2-1)^2-2^2} + \frac{1}{(2.4^2-1)^2-4^2} + \frac{1}{2.6^2-1)^2-6^2} + \cdots\right]$$

Besides these Nīlakaṇṭha (1500 A.D.) deals with many other series which show that the author had the knowledge of slowly converging series.

Sine and Cosine Series :—

The Sine and Cosine series were perhaps first developed by Mādhava (c. 1400 A.D.). The rules are also found in the *Karaṇapaddhati*.

cāpācca tattat phalato'pi tadvat cāpān atāddvyādihatāt trimaurvyā |
labdhāni tattat phaldto'pi tadvat cāpāhatād dvyādihatāt trimaurvyā ||
vinyasya coparyupari tyajet tat śeṣau bhūjyākoṭigunau bhavetām ||
(*Karaṇapaddhati*, ch. 6, v. (12-13 ab)

"The arc is multiplied by itself (for a definite number of times) and the product is multiplied once again by the same arc. The result is divided by the product obtained by multiplying 2, 3........etc. (upto the same definite number) with the radius repeatedly multiplied by itself (the same number of times). The quotients thus obtained for the even values of (definite) numbers (upto which the aforesaid multiplication is repeatedly done) are set one below the other (in one column) and likewise those corresponding to the odd values of (definite) numbers (in another column). From the first term is subtracted the term immediately below and so on for every column. All the values thus obtained in the case of the even column are subtracted together from the arc and the corresponding values for the odd column together form the radius. The results are the *bhujajyā* and *koṭijyā* respectively.

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To explain the rule in the circle (fig. 4),

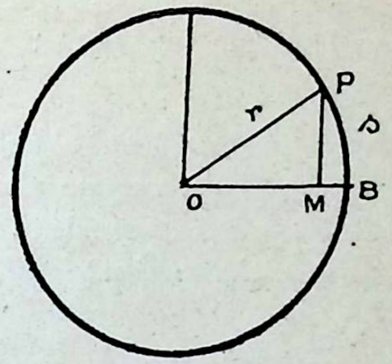

Fig.4

BP=*cāpa*, s

OP=*trimaurvyā*, or radius, r

PM=*bhujajyā*, r sin θ

OM=*koṭijyā*, r cos θ

If n be the number of times upto which the arc s be multiplied by itself, the first part of the rule gives the quotient as,

$$q_n = \frac{s^n \cdot s}{(2.3\ldots\ldots n \text{ terms}) \times r^n}$$

$$= \frac{s^{n+1}}{(n+1)!\, r^n}$$

In the next step, the even quotients $q_2, q_4, q_6\ldots\ldots$ are set down in a column and difference (q_2-q_4), $(q_6-q_8)\ldots\ldots\ldots$etc. are determined. Similarly by arranging the odd quotients in another column, the differences (q_1-q_3), $(q_5-q_7)\ldots\ldots\ldots$etc. are obtained.

Then *bhujajyā* is given by,

$$r \sin\theta = s - (q_2 - q_4) - (q_6 - q_8)\ldots\ldots\ldots\ldots\ldots$$

$$= s - \left(\frac{s^3}{3!\,r^2} - \frac{s^5}{5!\,r^4}\right) - \left(\frac{s^7}{7;\,r^6} - \frac{s^9}{9!\,r^8}\right) - \ldots\ldots$$

$$\text{or } \sin\theta = \frac{s}{r} - \frac{1}{3!}\left(\frac{s}{r}\right)^3 + \frac{1}{5}\left(\frac{s}{r}\right)^5 - \frac{1}{7}\left(\frac{s}{r}\right)^7 + \frac{1}{9}\left(\frac{s}{r}\right)^9 - \ldots\ldots$$

Koṭijyā is given by,

$$r \cos\theta = r - (q_1 - q_3) - (q_5 - q_7) - \ldots\ldots\ldots\ldots$$

$$= r - \frac{s^2}{2!\,r} + \frac{s^4}{4!\,r^3;} - \frac{s^6}{6!\,r^5;} + \frac{s^8}{8!\,r^7;} - \ldots\ldots\ldots\ldots$$

$$\text{or} \quad \text{Cos}\,\theta = 1 - \frac{1}{2!}\left(\frac{s}{r}\right)^2 + \frac{1}{4!} - \left(\frac{s}{r}\right)^4 - \frac{1}{6}\left(\frac{s}{r}\right)^6 - \ldots\ldots\ldots$$

From these the modern forms can readily be obtained by putting $s = r\,\theta$, for small values of s and θ as follows :

$$\sin\theta = \theta - \frac{\theta^3}{3!.} + \frac{\theta^5}{4!} - \ldots\ldots\ldots$$

$$\cos\theta = 1 - \frac{\theta^2}{2!} + \frac{\theta^4}{4!} - \ldots\ldots\ldots$$

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Tan series :

The rule runs thus :

vyāsārdhena hatād abhīṣṭaguṇataḥ koṭyaptamādhaṃ phalaṃ
jyāvargeṇa virighnomādiphalaṃ tattatphalaṃ cāharet
kṛtvā koṭiguṇasya tatra tu phaleṣvekatripañcādibhir—
bhaktesvojayutaistyajet samajutiṃ jīvādhanuśiśayate !!

(*Karaṇapaddhati*, ch. 6, v. 18)

'*Jyā* of the arc (*dhanus*) is to be multiplied by the semi-diameter (*vyāsārdha*) and is divided by the *koṭi*. This is the first term (of the tan series). The value of the first term when multiplied by the square of the *jyā* and divided by the square of the *koṭi* gives the second term. This process is repeated. The successive terms are divided by the old integer 1, 3, 5............ Now, when the consecutive terms in the series starting from the first term are alternately subtracted and added gives the circumference".

$$\text{arc BP} = \text{OP}\left[\frac{\text{PM}}{\text{OM}} - \frac{1}{3}\,\frac{\text{PM}^3}{\text{OM}^3} + \frac{1}{5}\,\frac{\text{PM}^3}{\text{OM}^3}\right] \quad \text{........(vide fig. 4)}$$

$$\text{or } s = r\left[\frac{r\sin\theta}{r\cos\theta}\quad \frac{1}{3}\left(\frac{r\sin\theta^3}{r\,\text{cose}\,\theta}\right)\frac{1}{5}\left(\frac{r\sin\theta}{r\,\text{cose}\,\theta}\right)^5 \cdots\cdots\cdots\right]$$

$$\text{Hence } \theta = \tan\theta - \frac{1}{3}\tan\theta^3 + \frac{1}{5}\,\text{tane}^5\,\theta \ldots\ldots\ldots \text{when } s = r\,\theta$$

The formula holds good if $\theta \geqq s\ 45^0$

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29. *antyādvargasthānād yatha labdham vargam viśodhayet* (Parameśvara's comm.) "Subtract the greatest square number from the last square place."

30. *prathama-sthānam ghana-samjnam dvitīye tṛtiye aghana-saṁjñnan caturthe ghana-samjnam, pancamaṣaṣṭhe aghanā samjnā anyapi* (Parameśvara's Comm.)

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